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**Deering**

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(54) **AIR BARRIER MATERIAL APPLICATION SYSTEMS AND METHODS**

(52) **U.S. Cl.**  
CPC ..... **B60C 5/14** (2013.01); **B05D 1/002** (2013.01); **B05D 1/02** (2013.01); **B05D 3/0218** (2013.01);

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(58) **Field of Classification Search**  
None  
See application file for complete search history.

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 386 days.

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*Primary Examiner* — William P Fletcher, III

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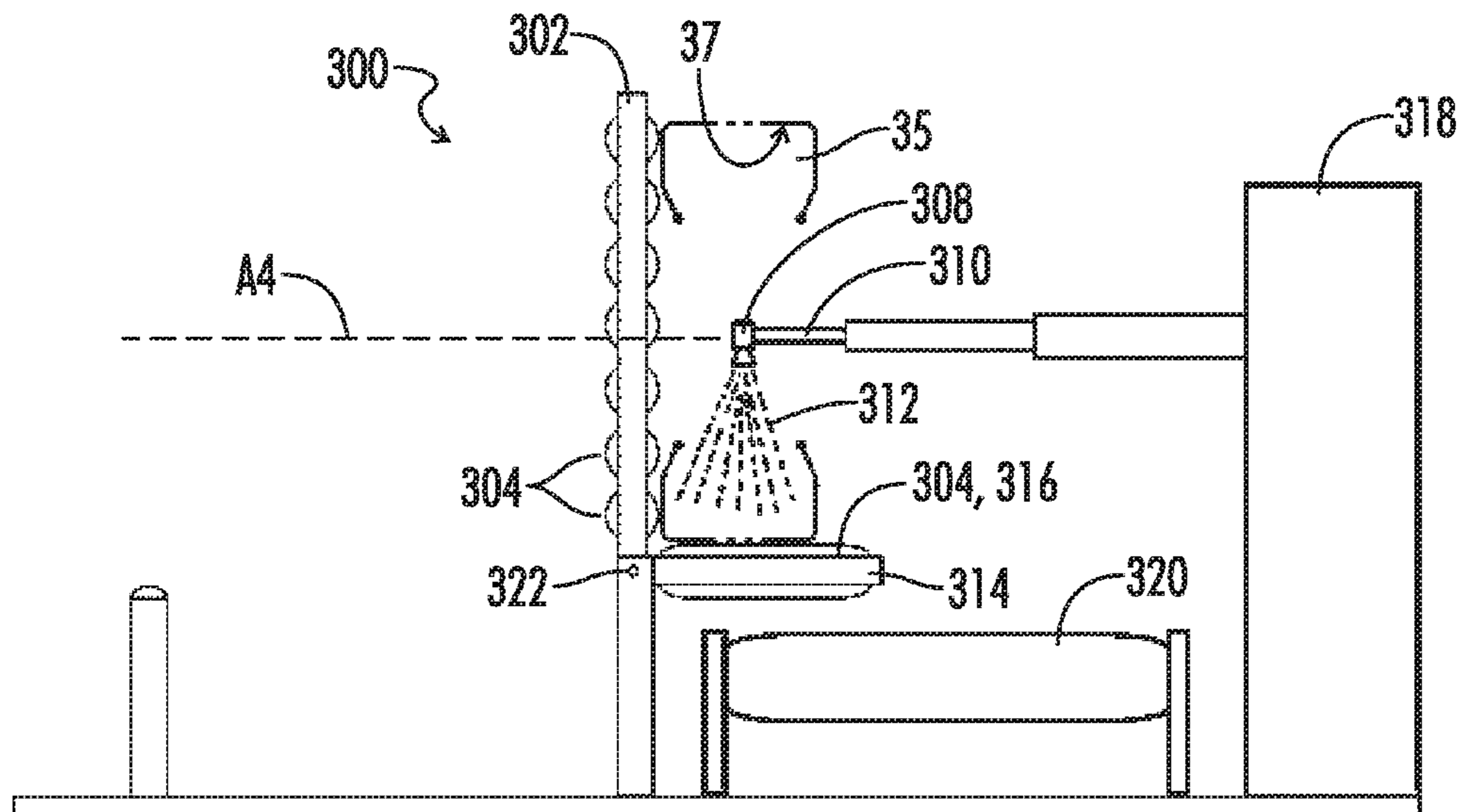
(57) **ABSTRACT**

A post-cure inflation machine for processing a tire may include a tire holder shaft. The tire holder shaft may include a chuck to secure the tire to the tire holder shaft. A hollow passage may be defined in the tire holder shaft. A spray nozzle may be connected to a spray shaft that is telescopically disposed in the hollow passage of the tire holder shaft. The spray nozzle may extend to spray an air barrier material onto the tire.

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**8 Claims, 24 Drawing Sheets**



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*B29D 30/00* (2006.01)
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 (2013.01); *B29D 30/0681* (2013.01); *B05D*  
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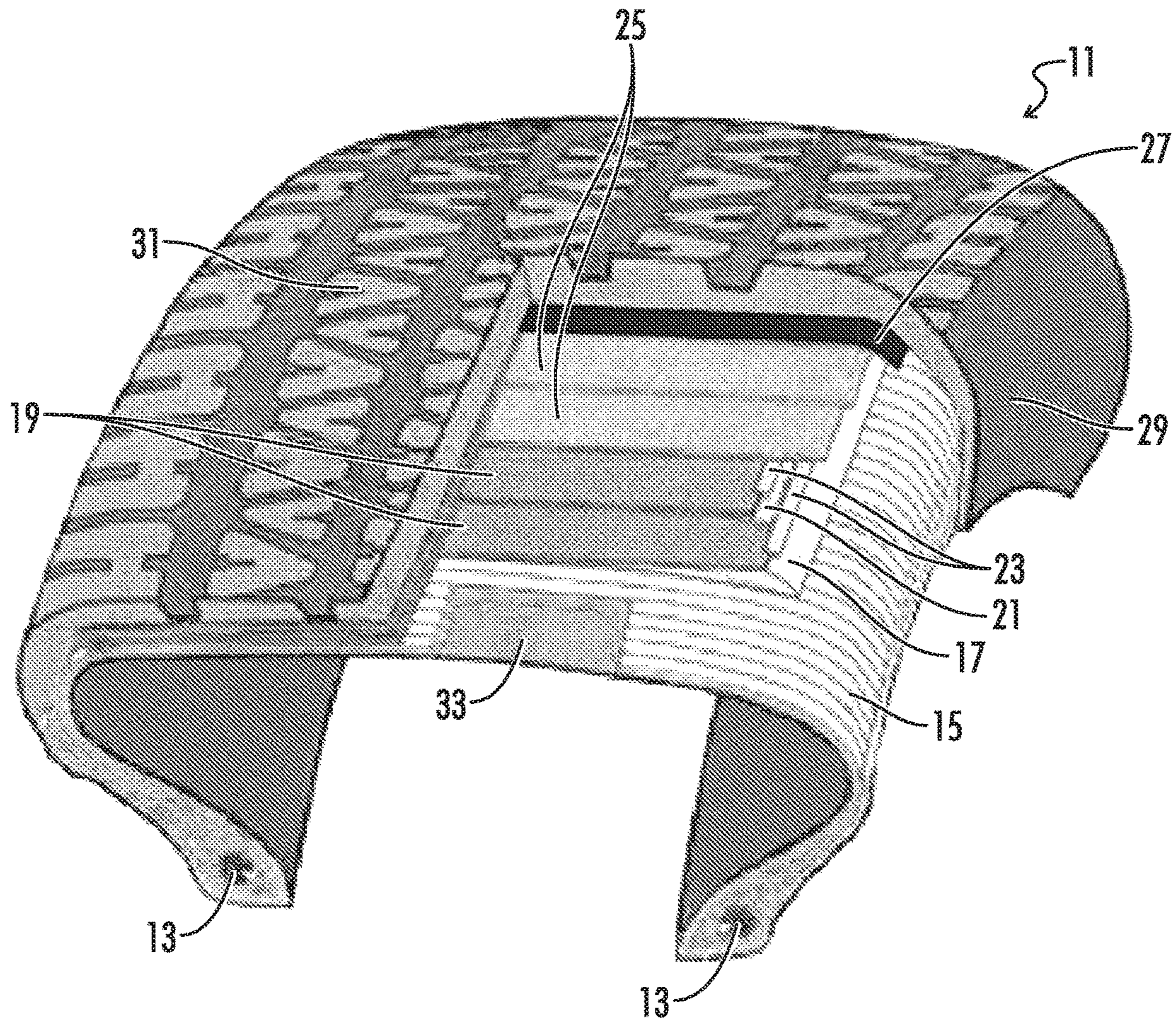


FIG. 1

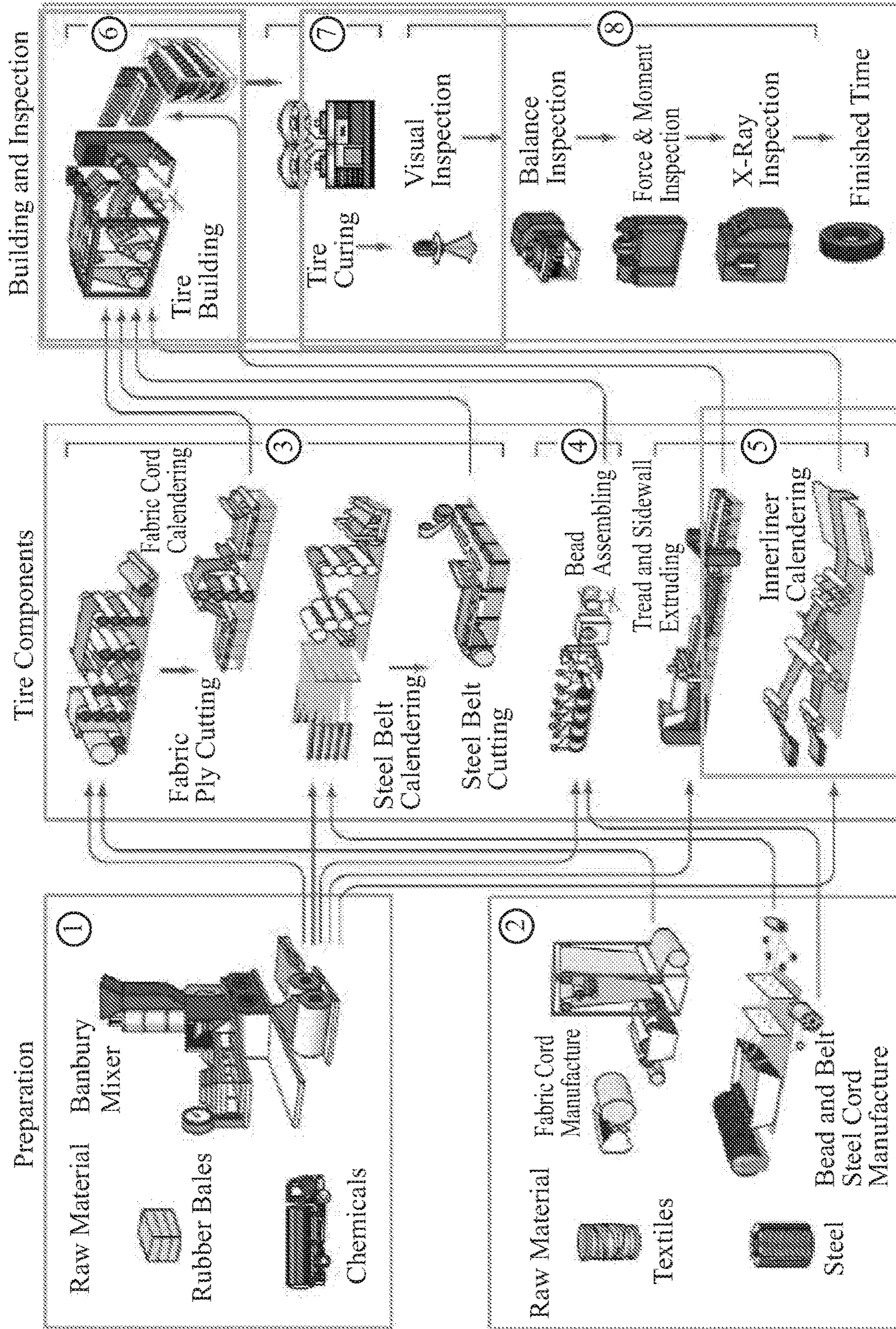


FIG. 2

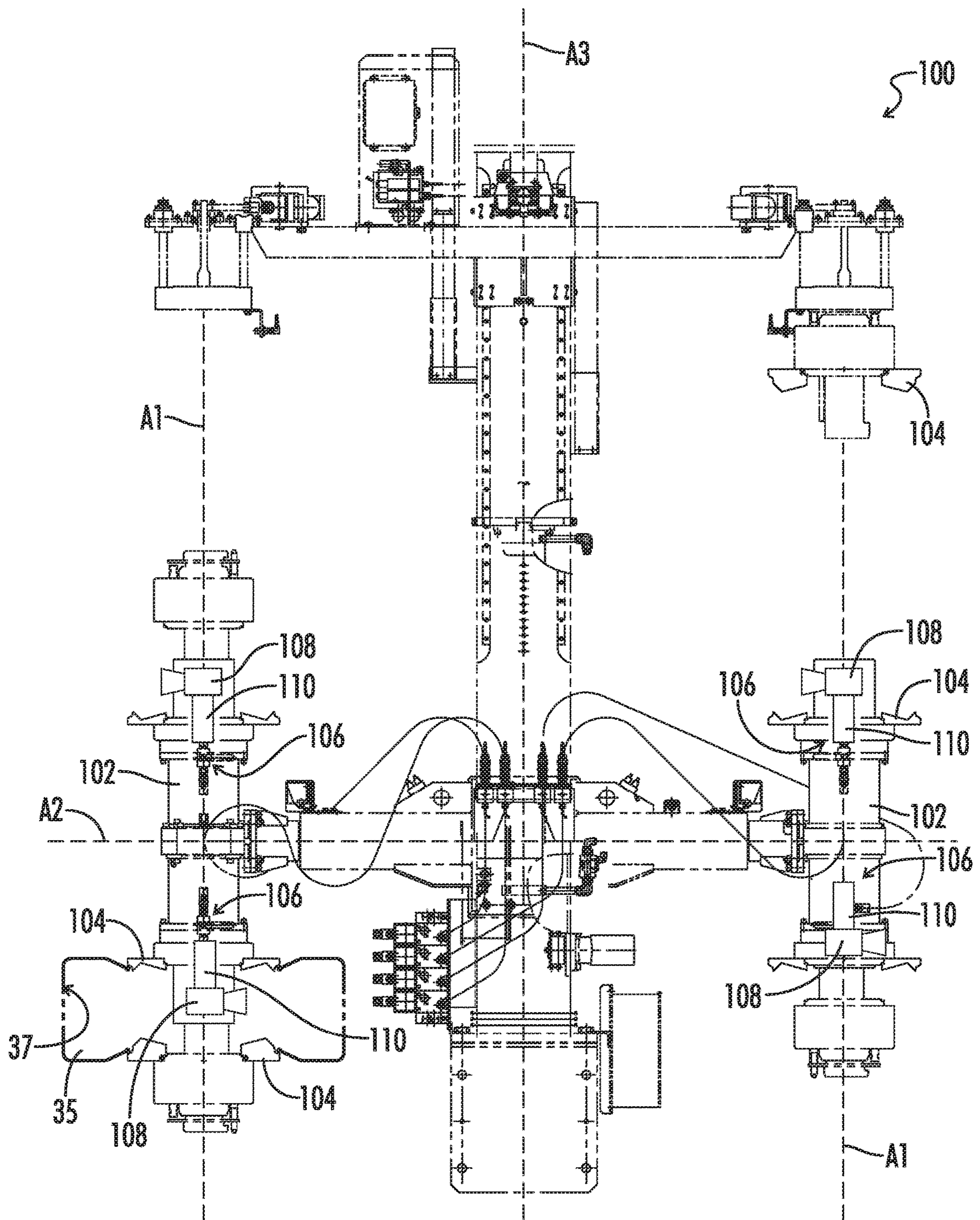
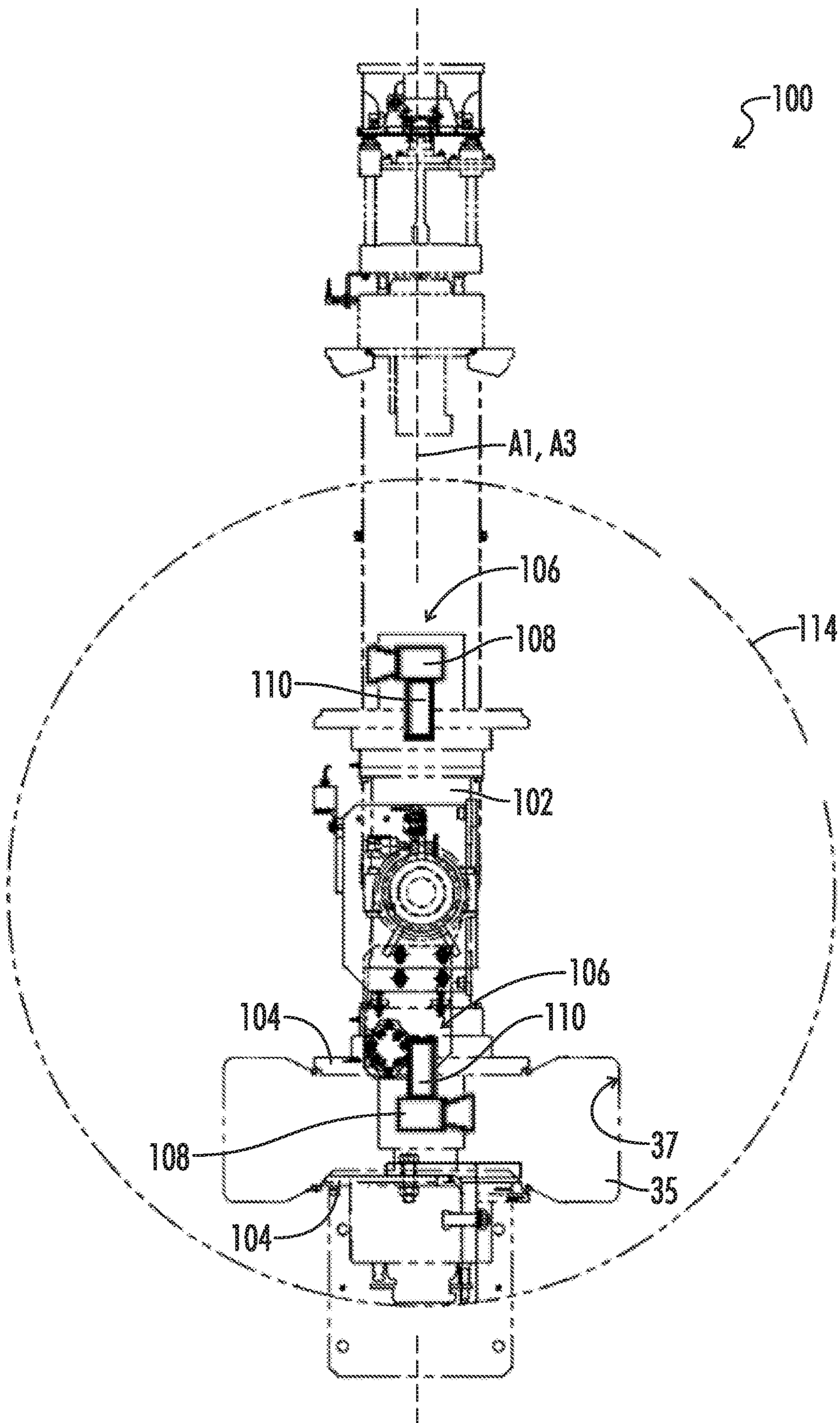


FIG. 3



**FIG. 4**

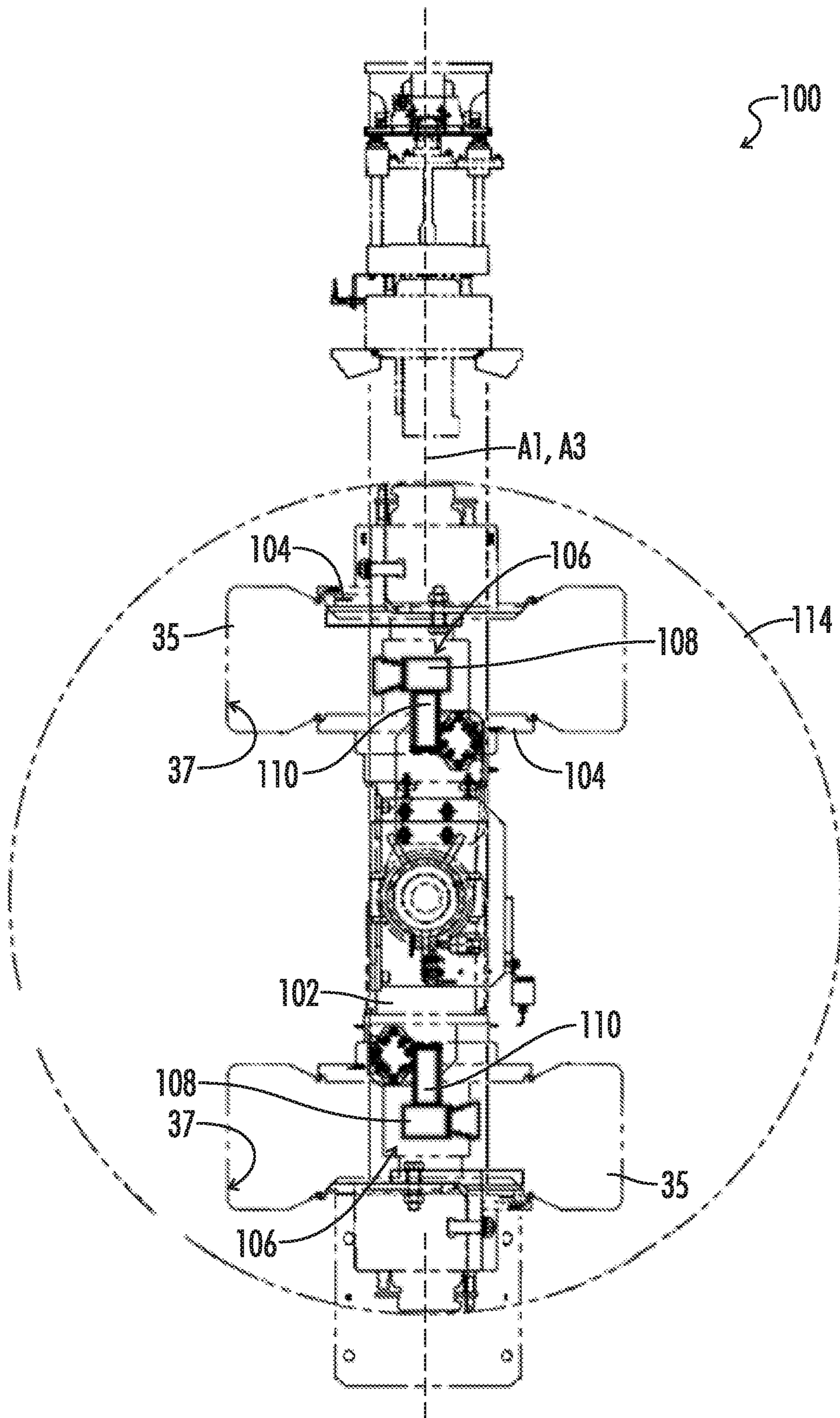


FIG. 5

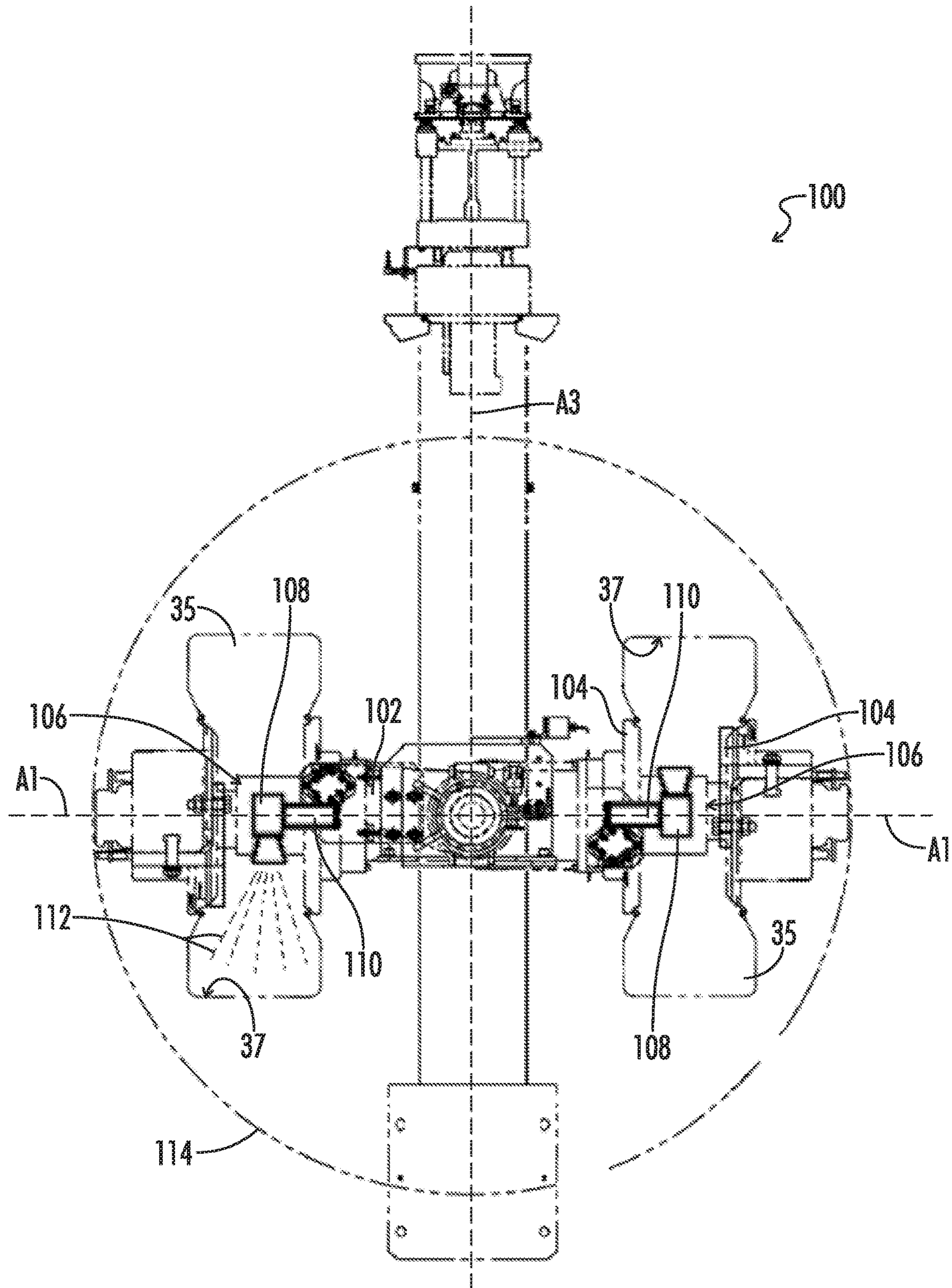
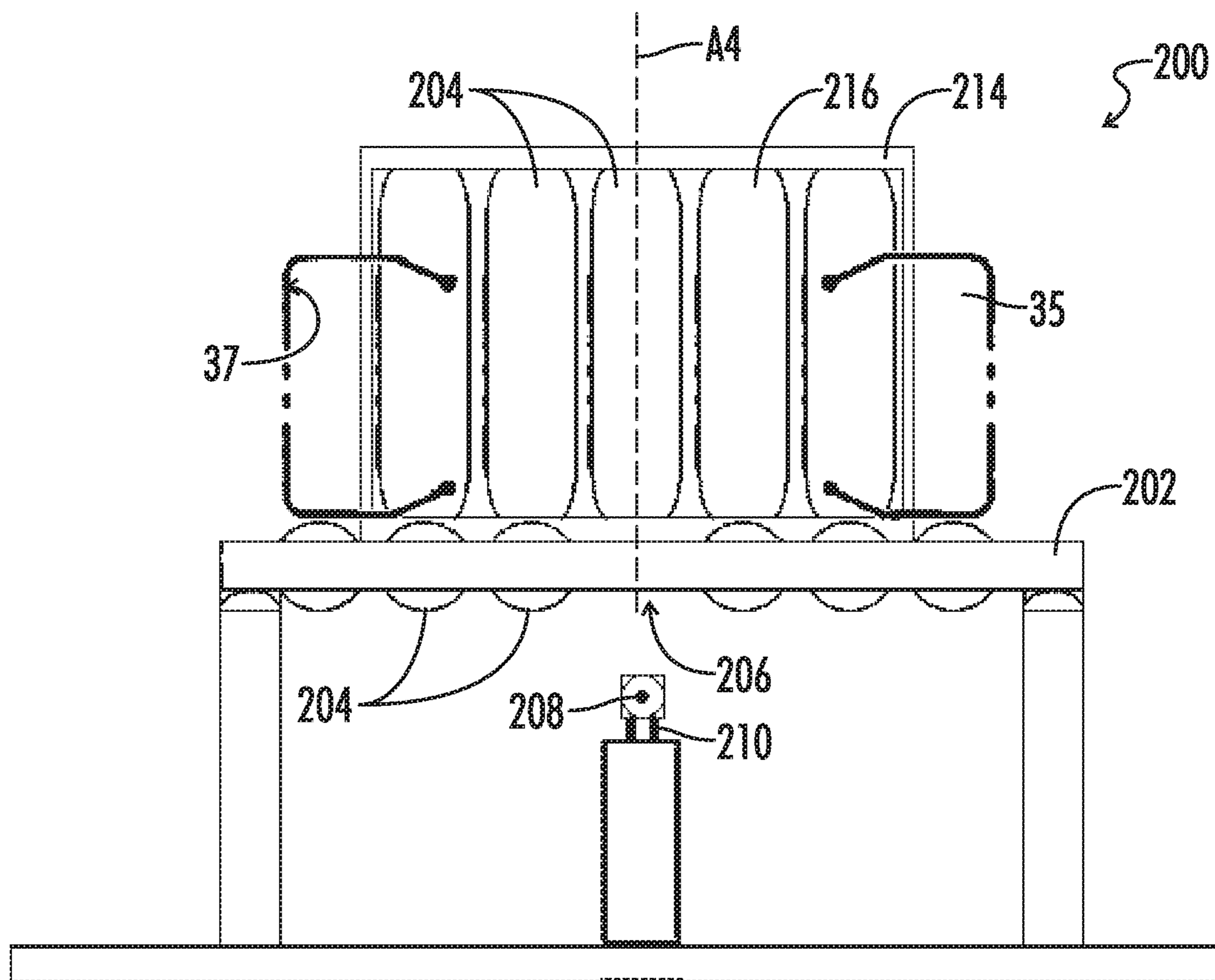
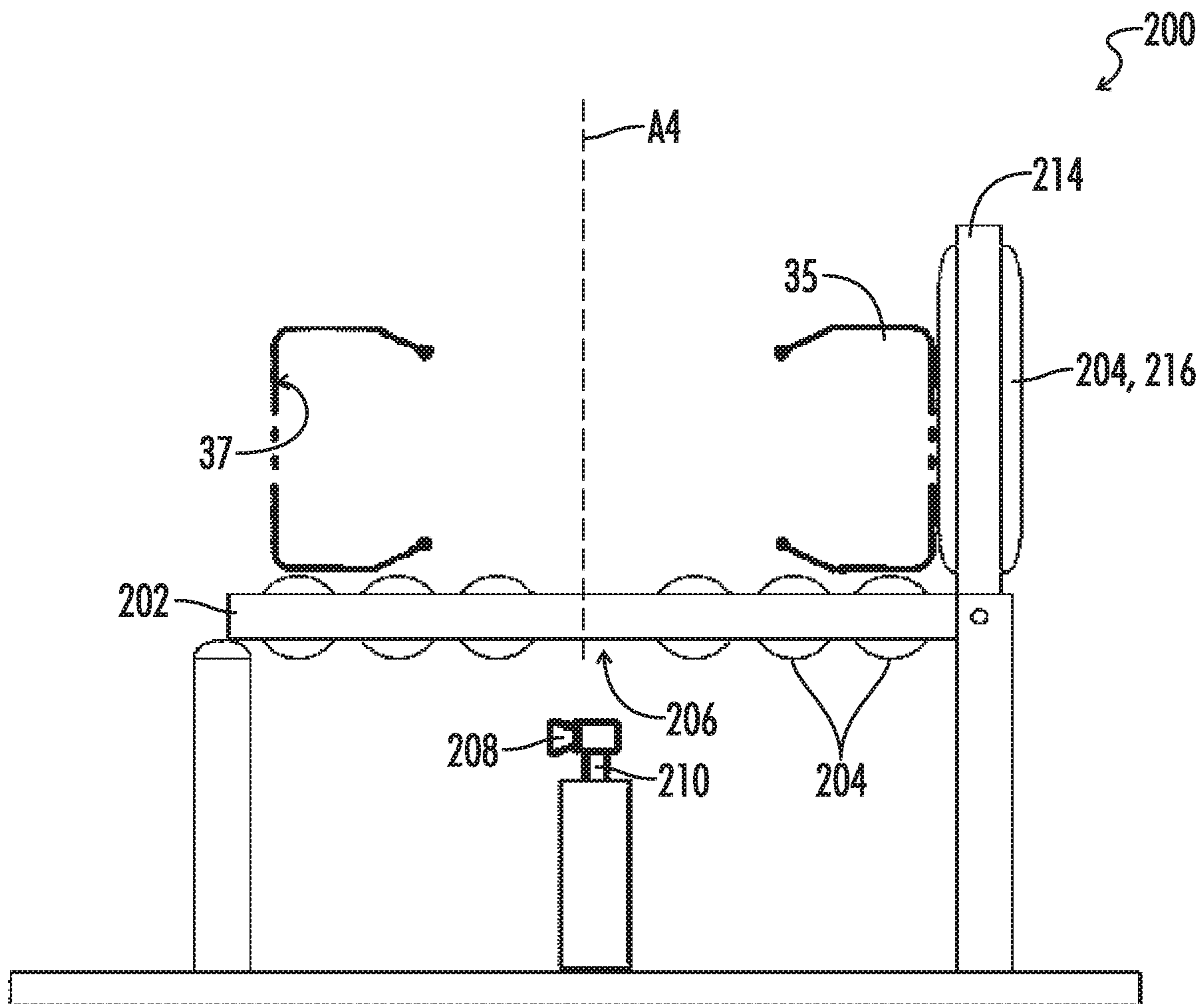


FIG. 6

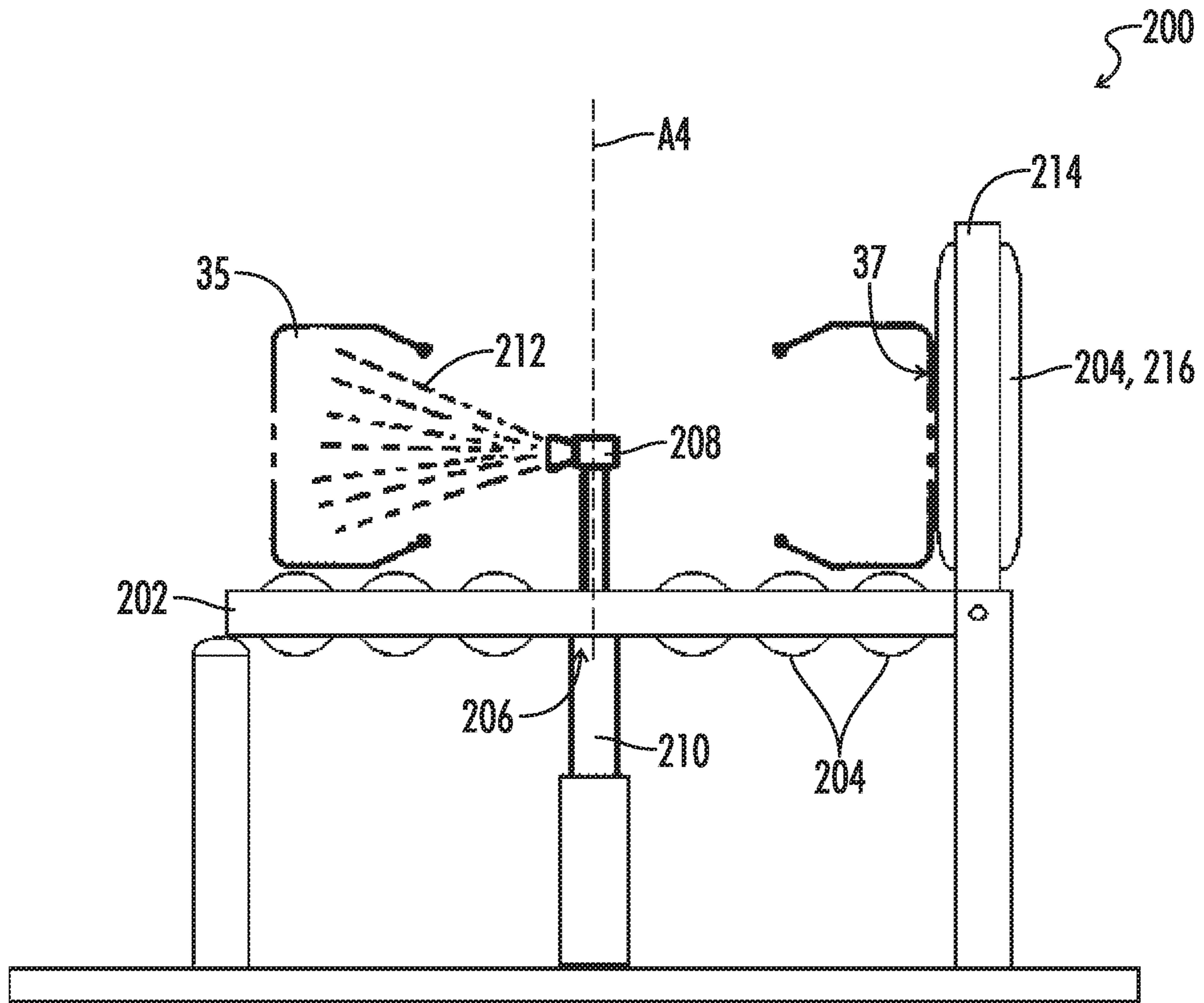




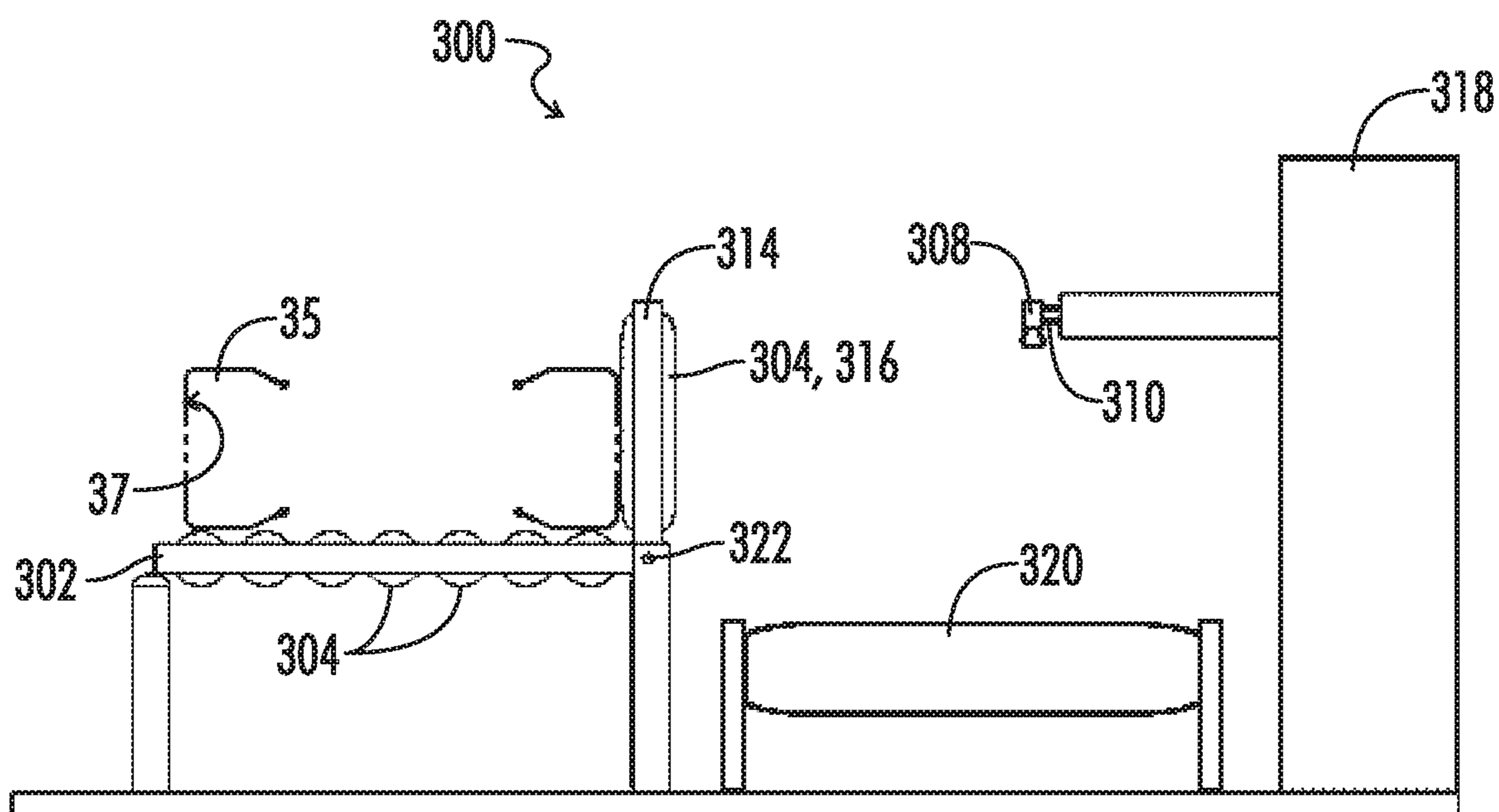
**FIG. 7**



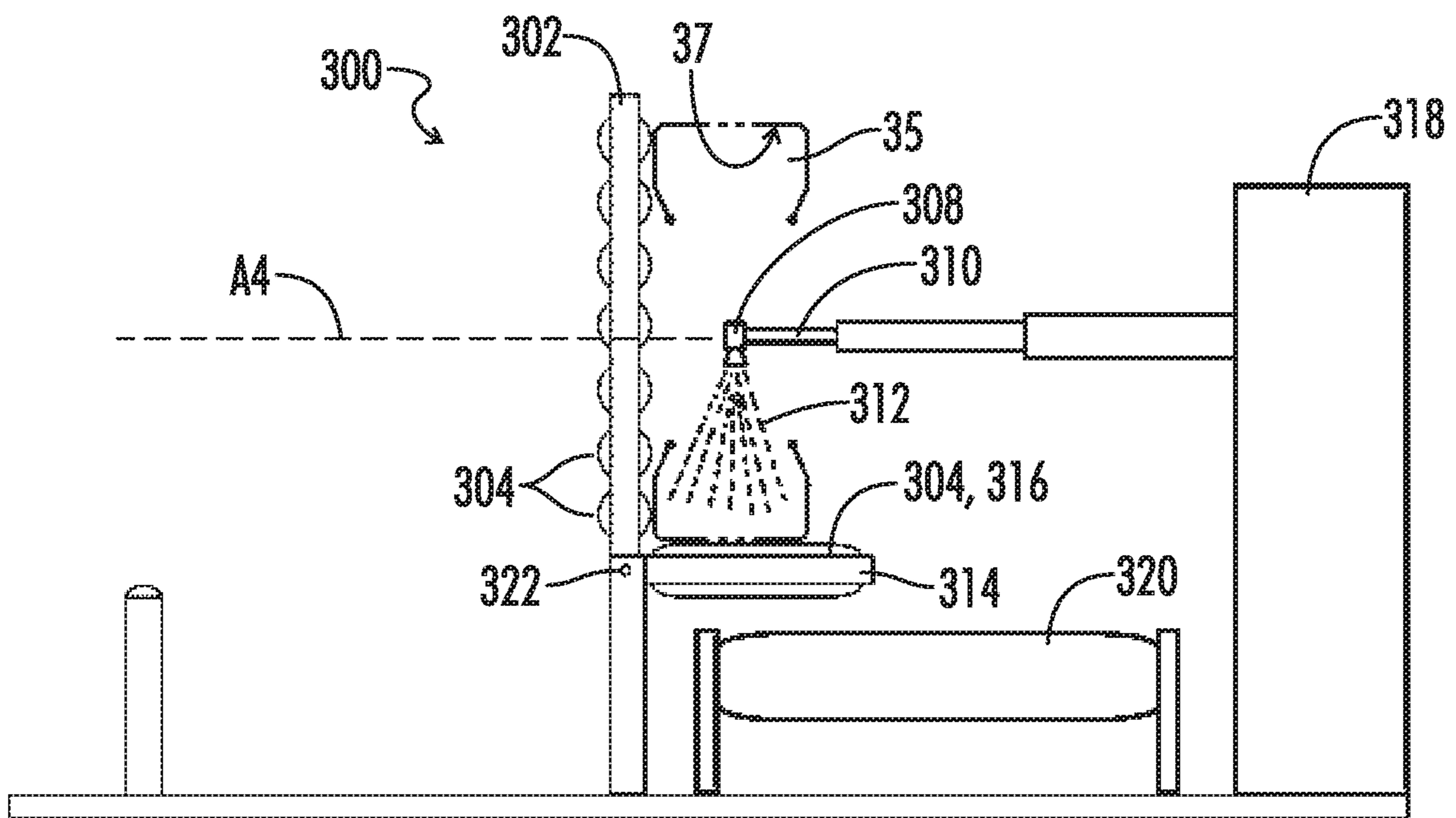
*FIG. 8*



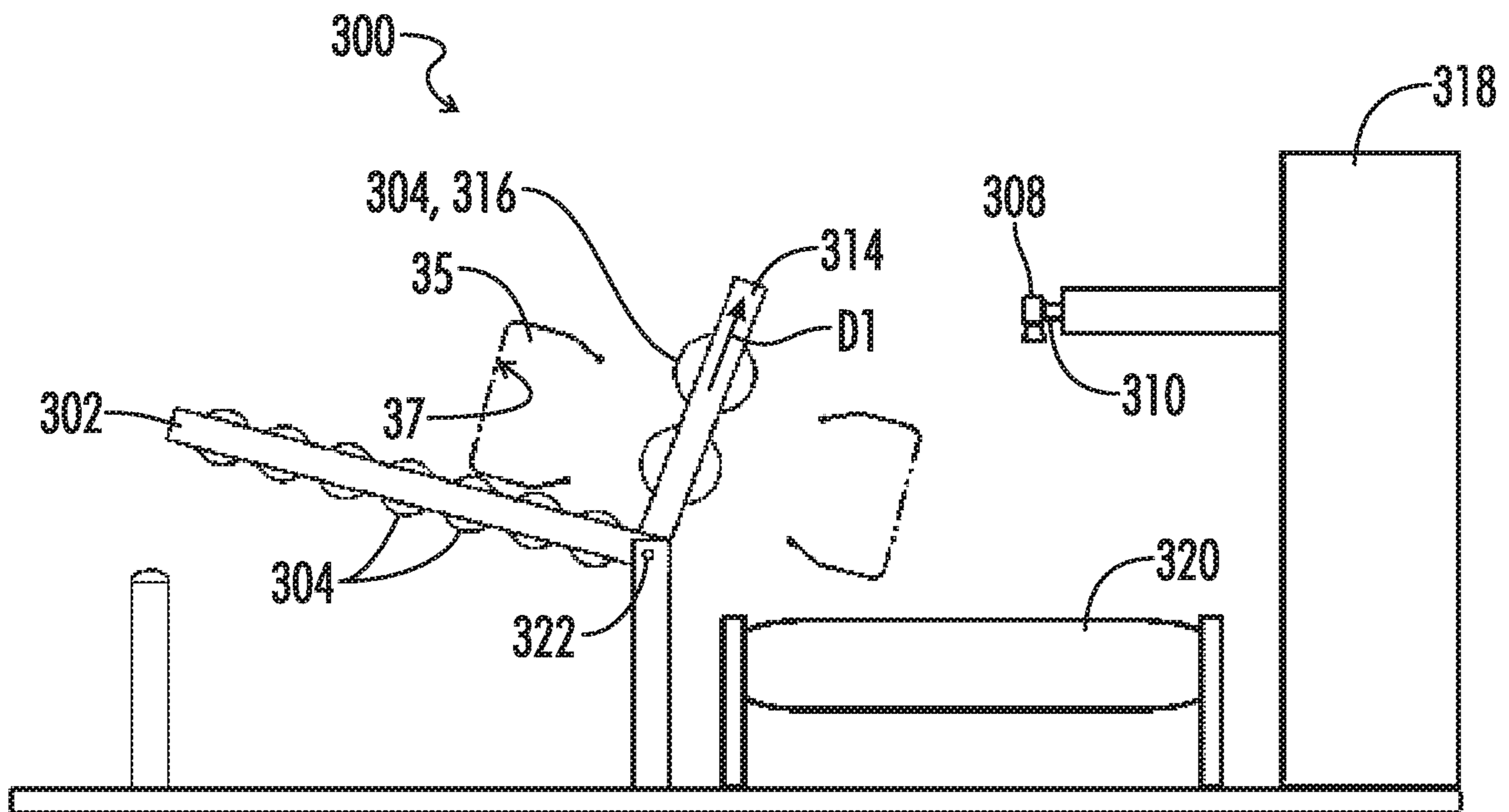
*FIG. 9*



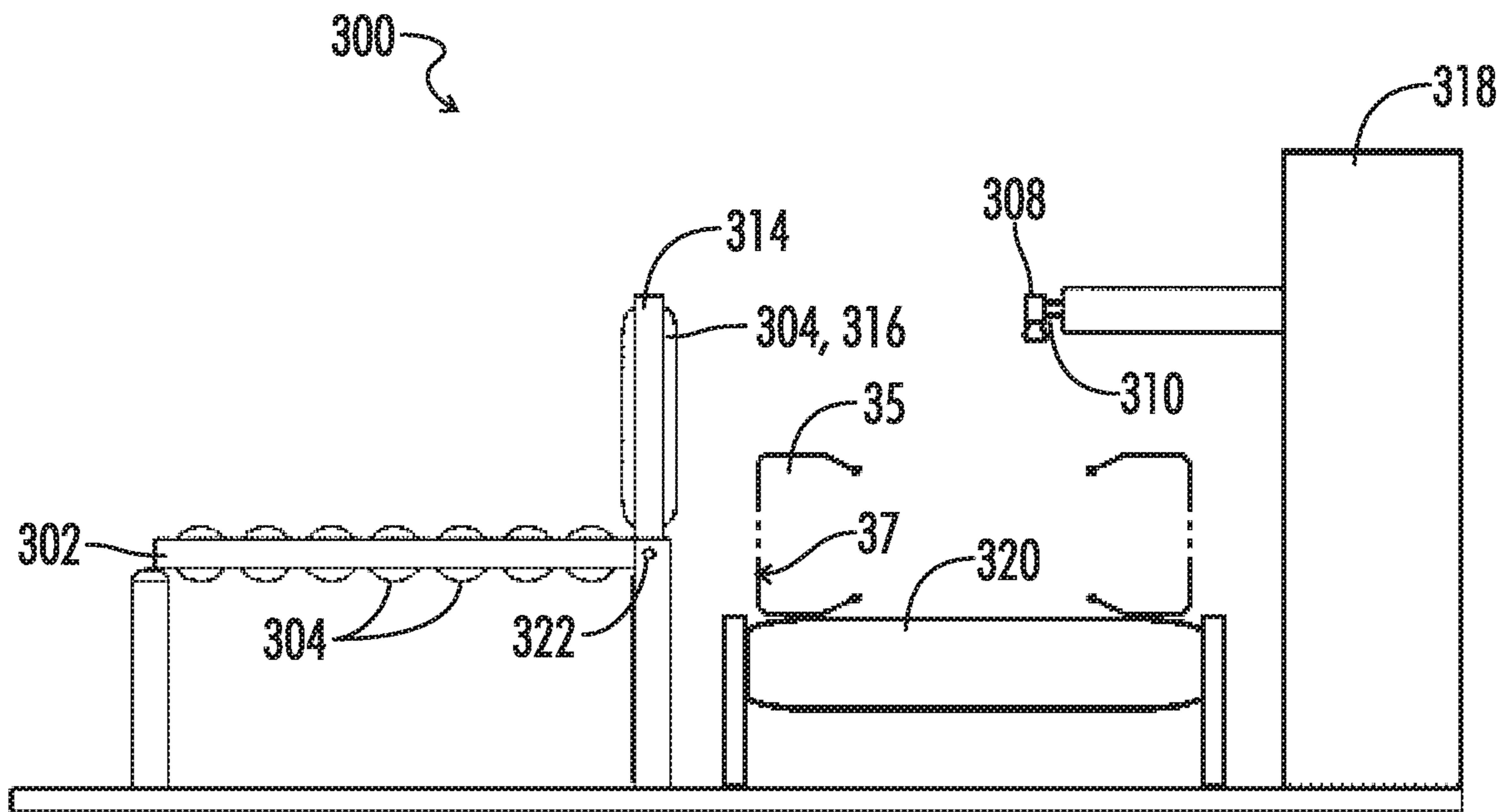
*FIG. 10*



**FIG. 11**



*FIG. 12*



**FIG. 13**

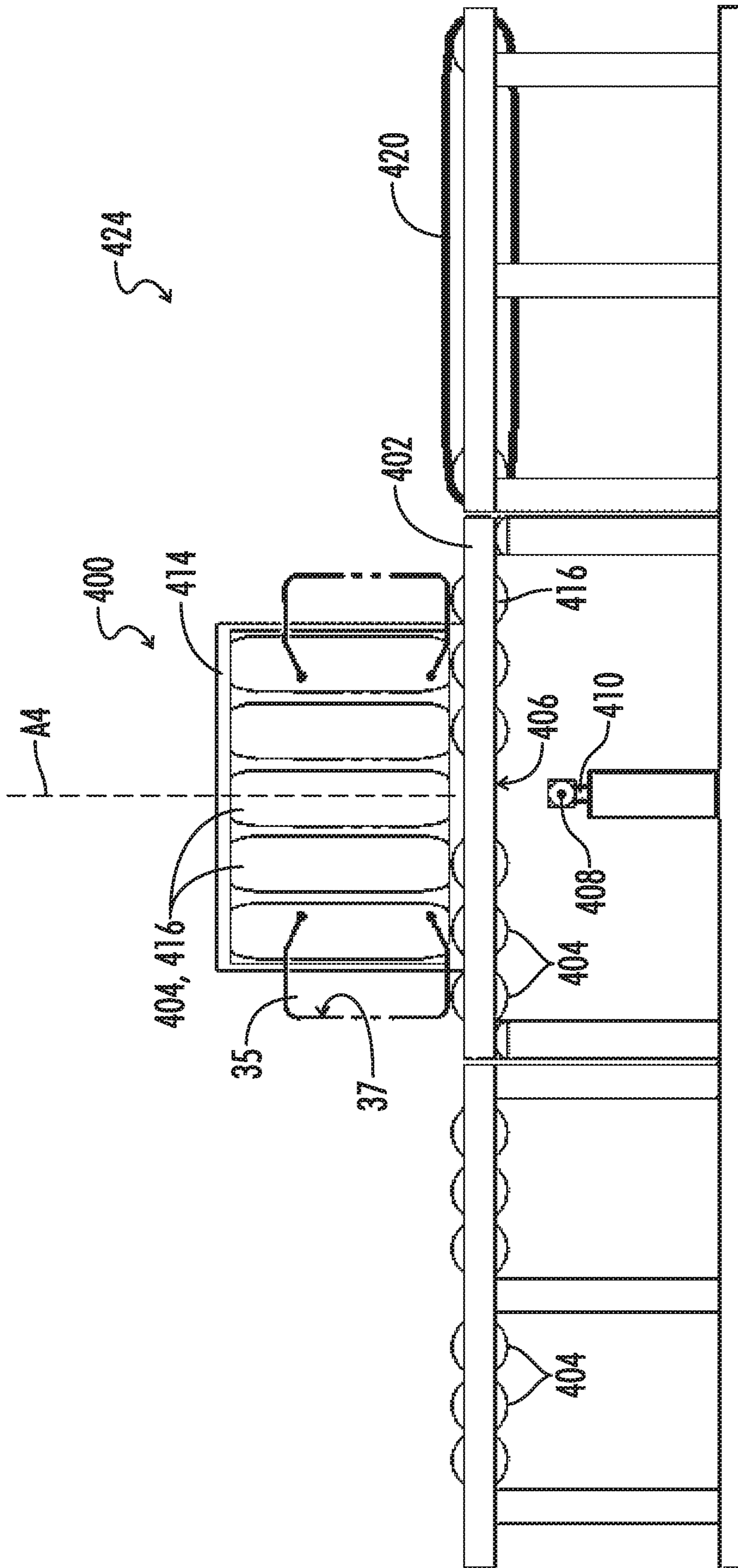


FIG. 14



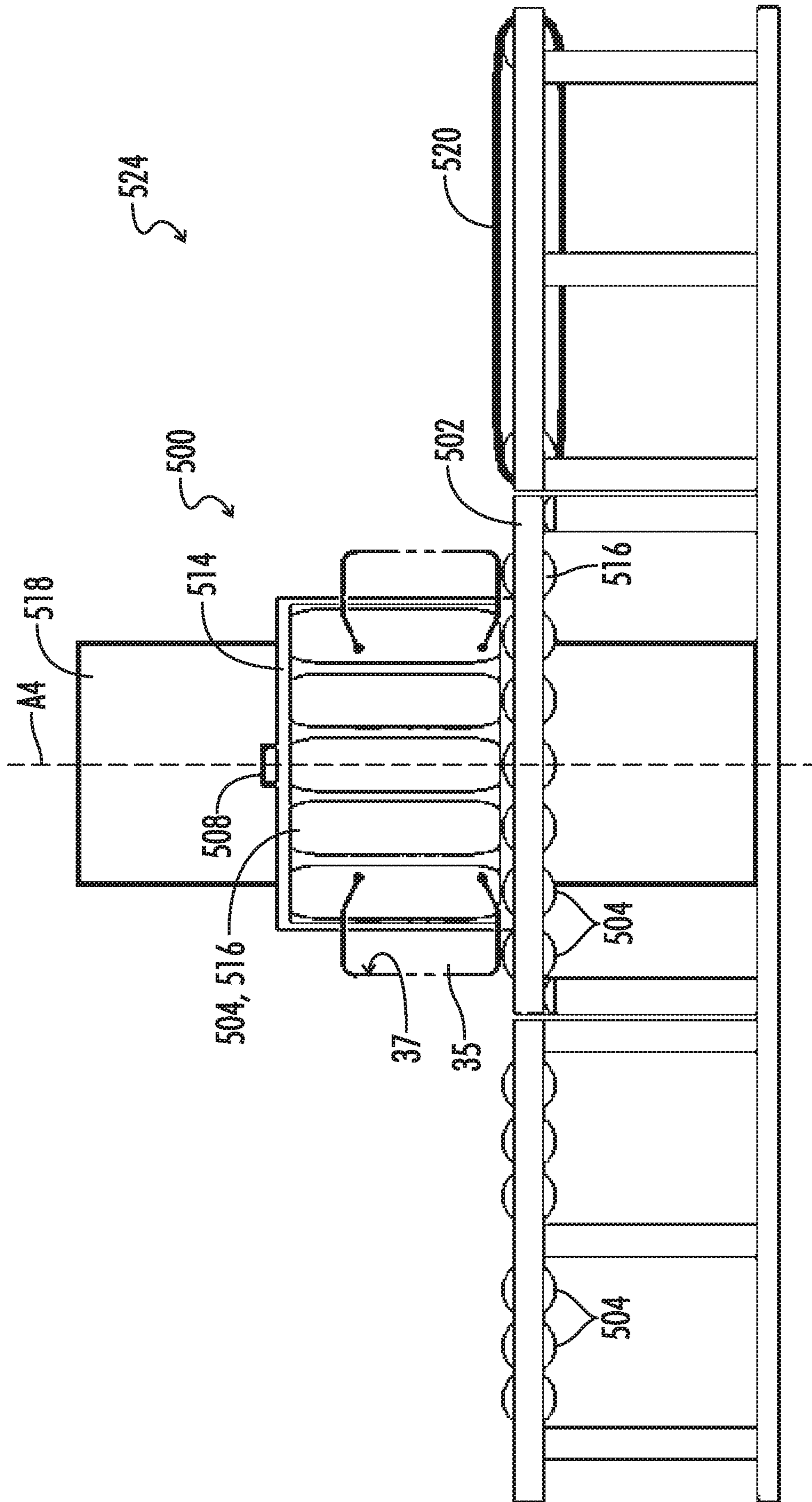
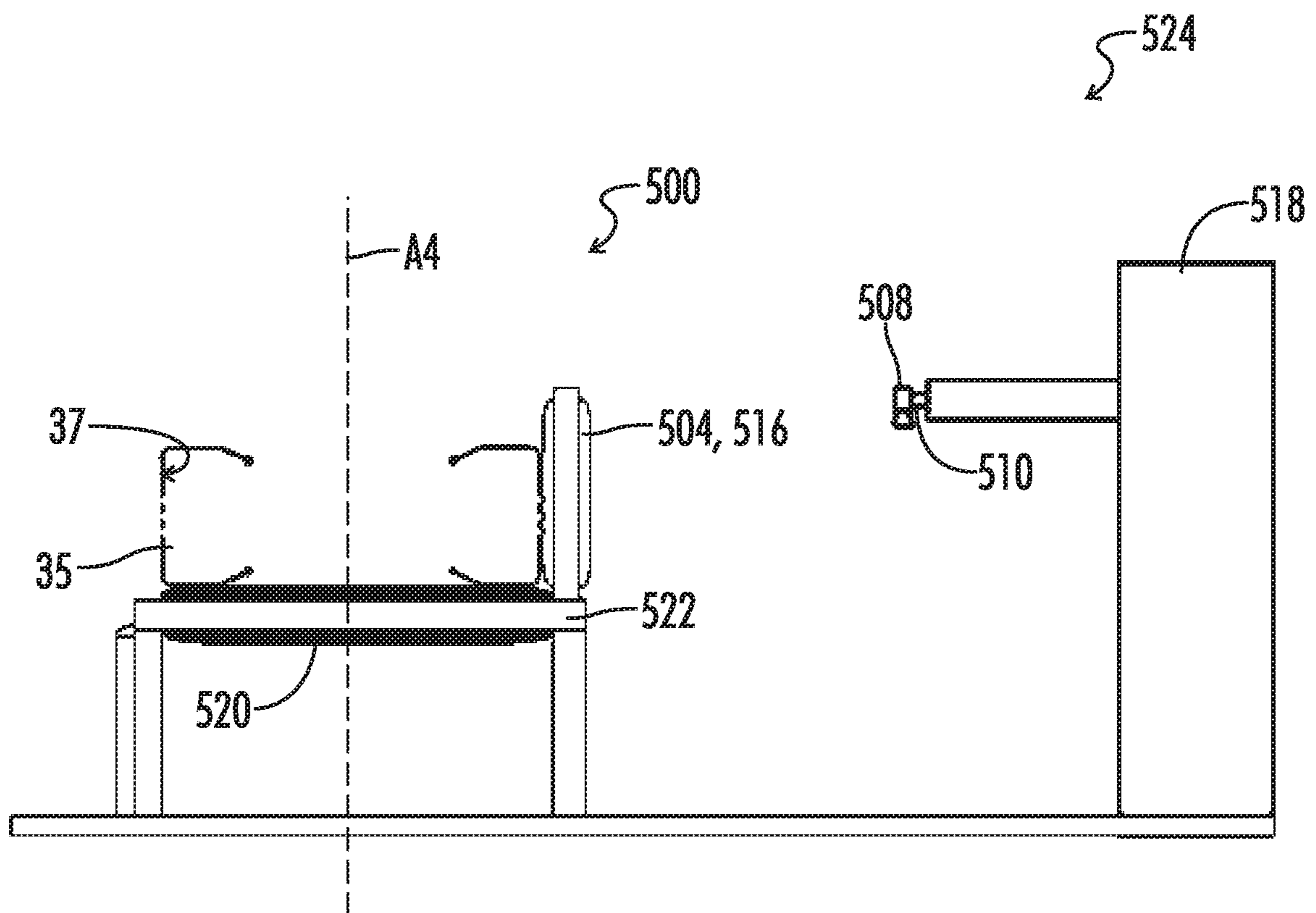
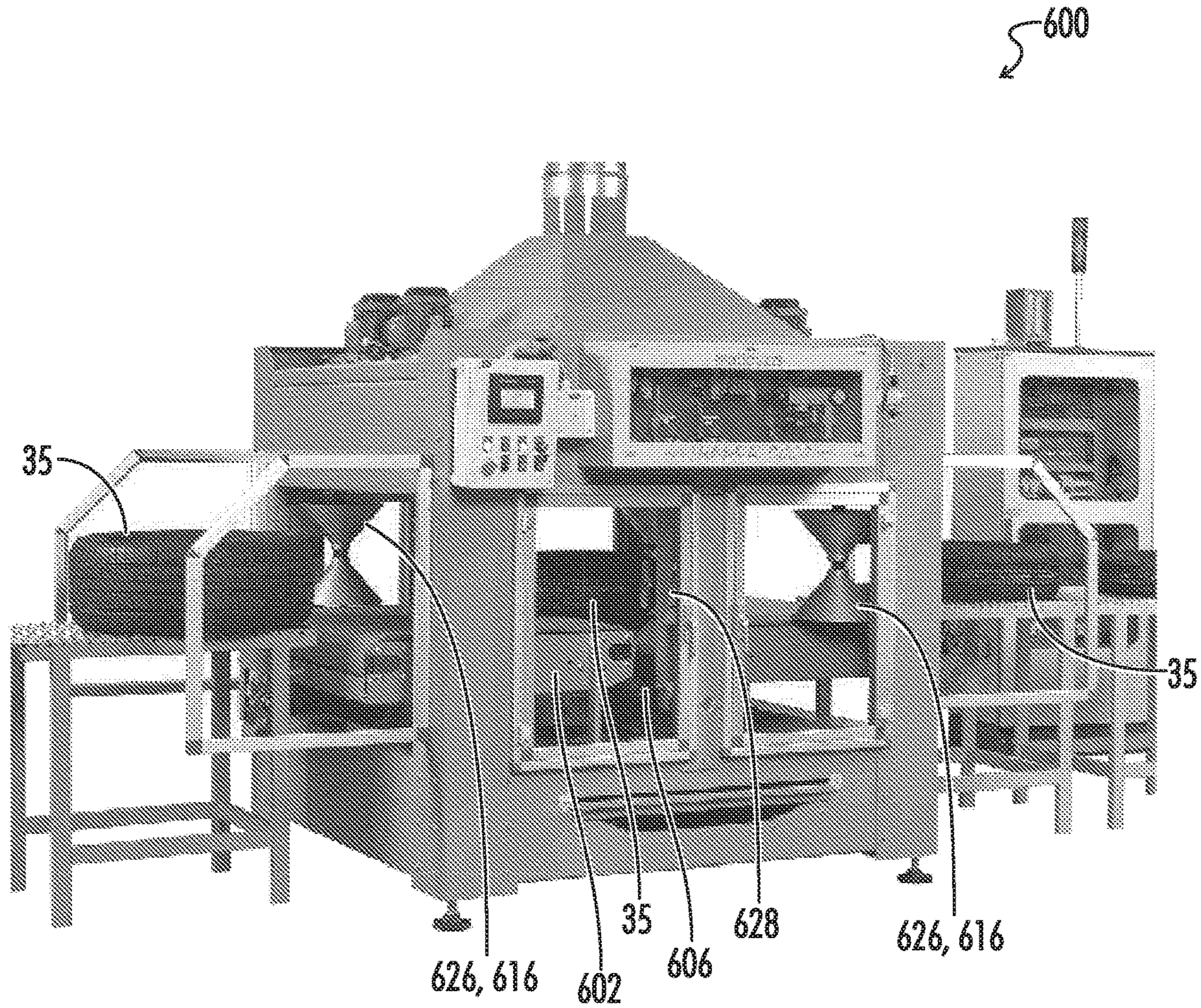


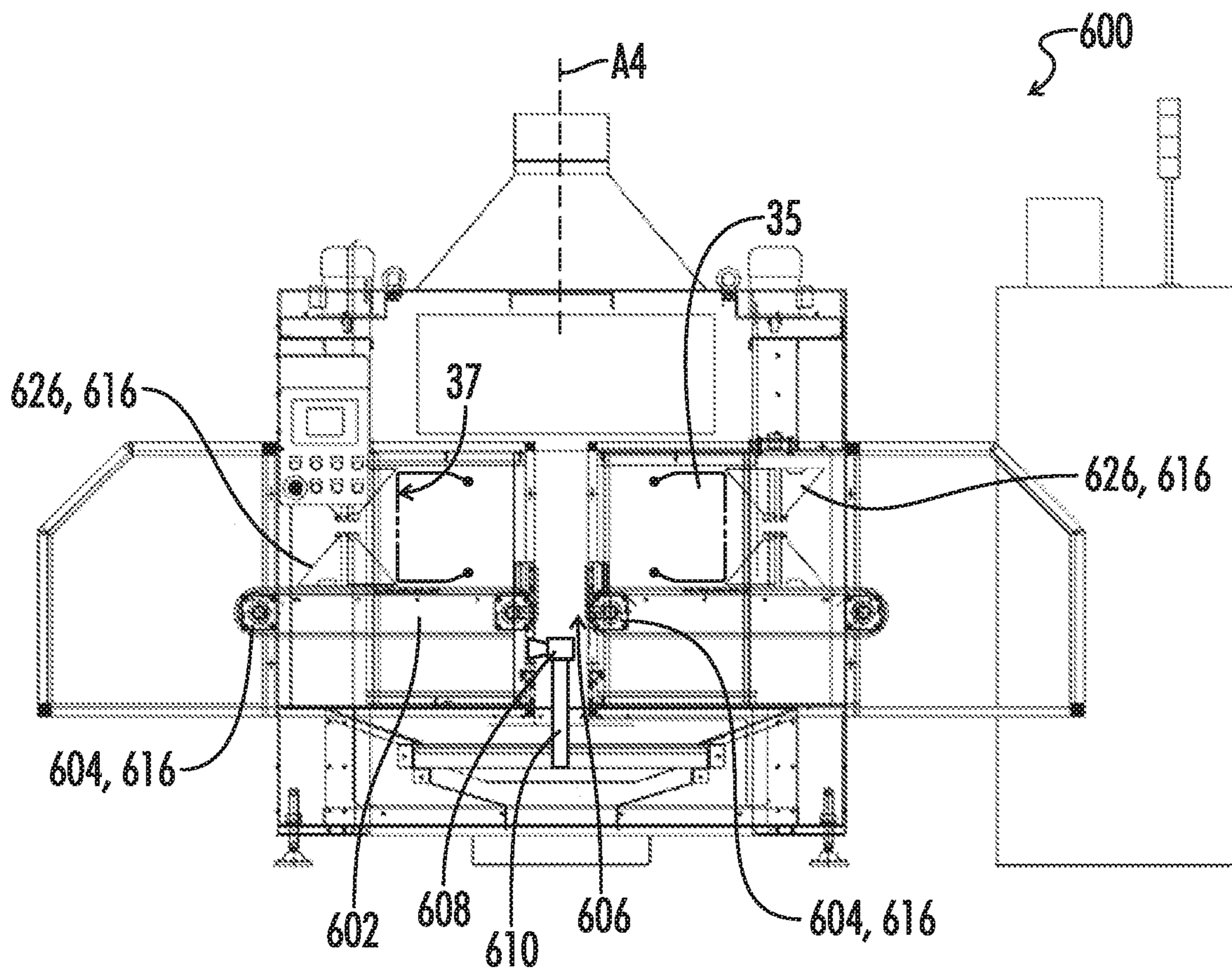
FIG. 15



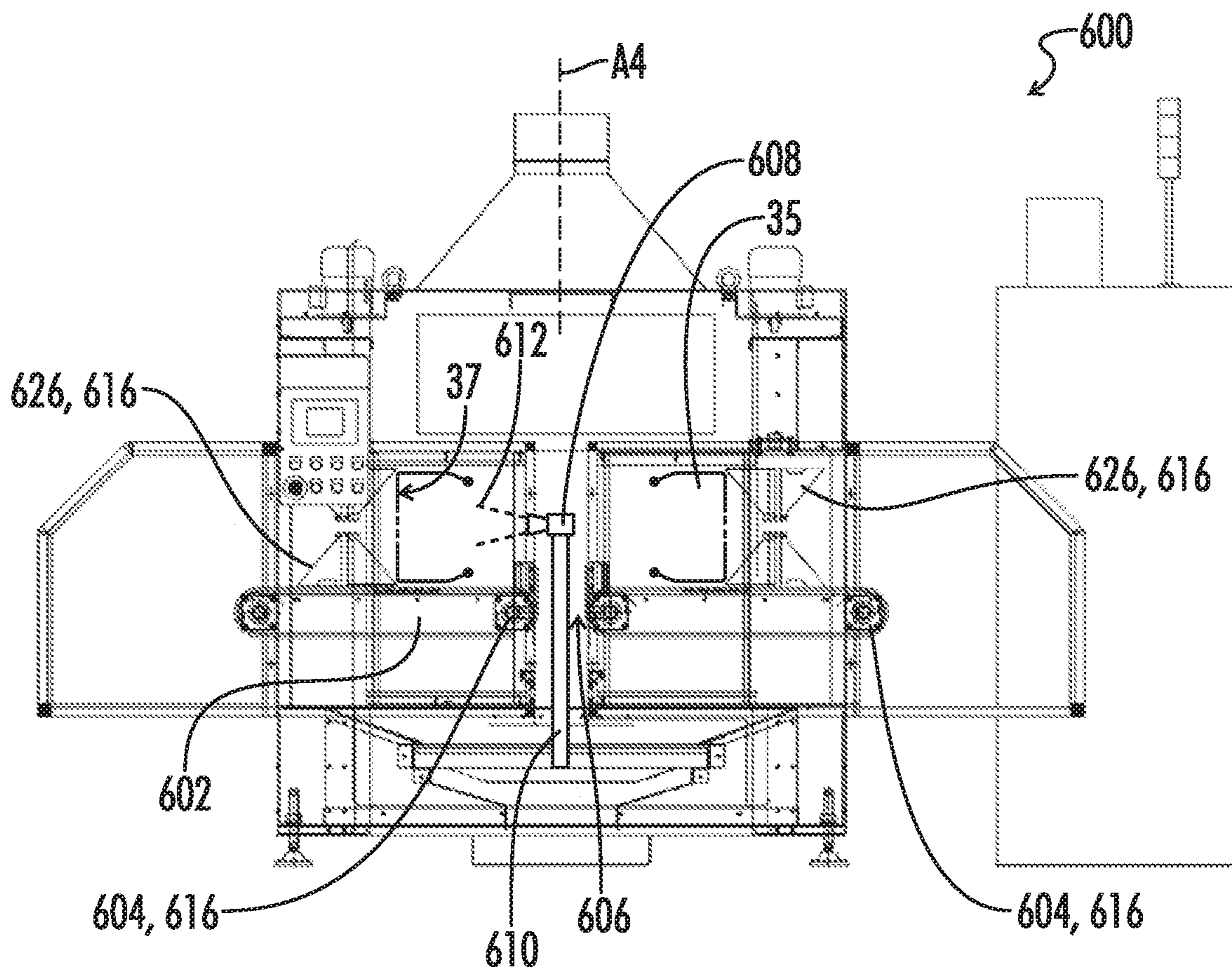
*FIG. 16*



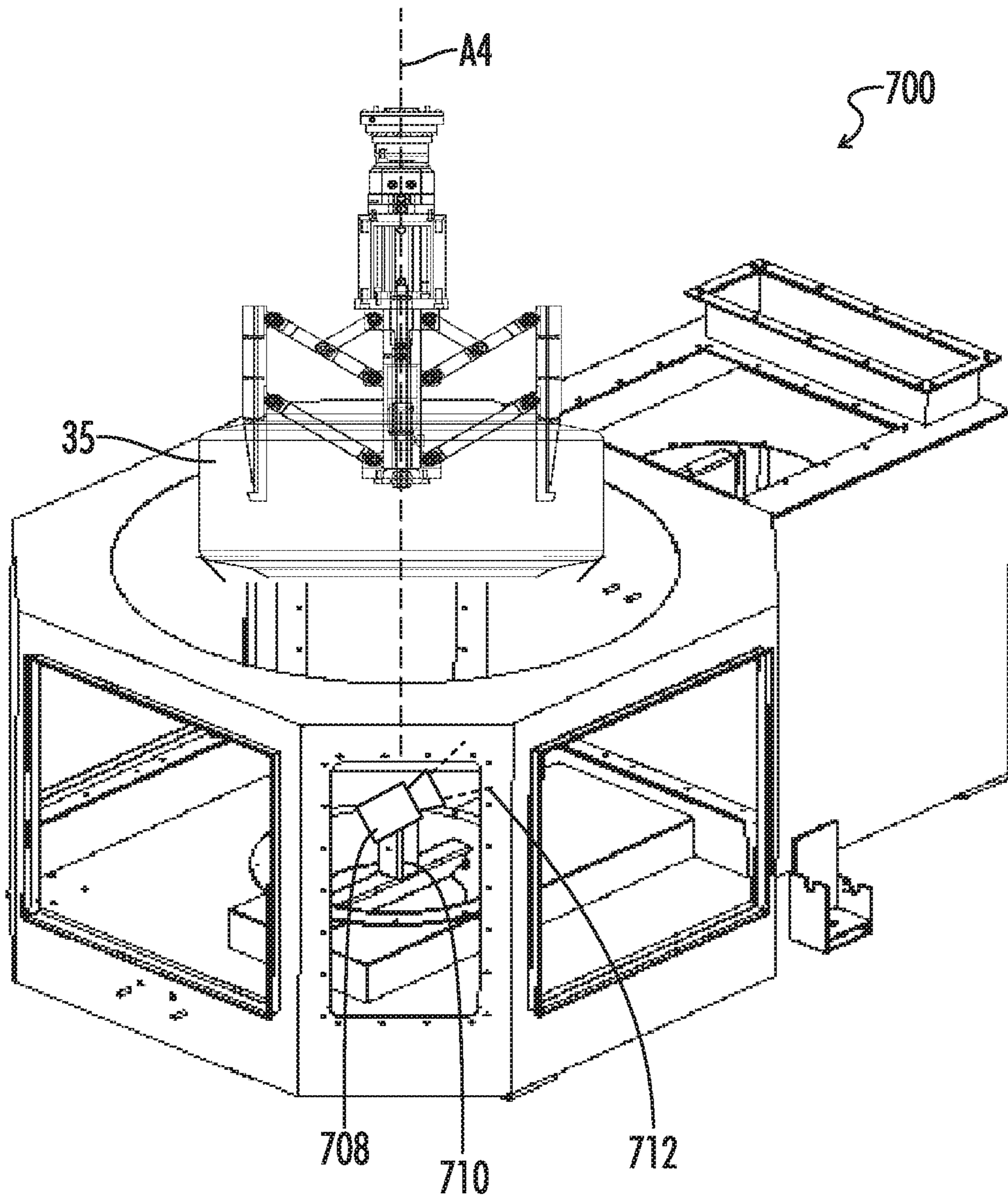
*FIG. 17*



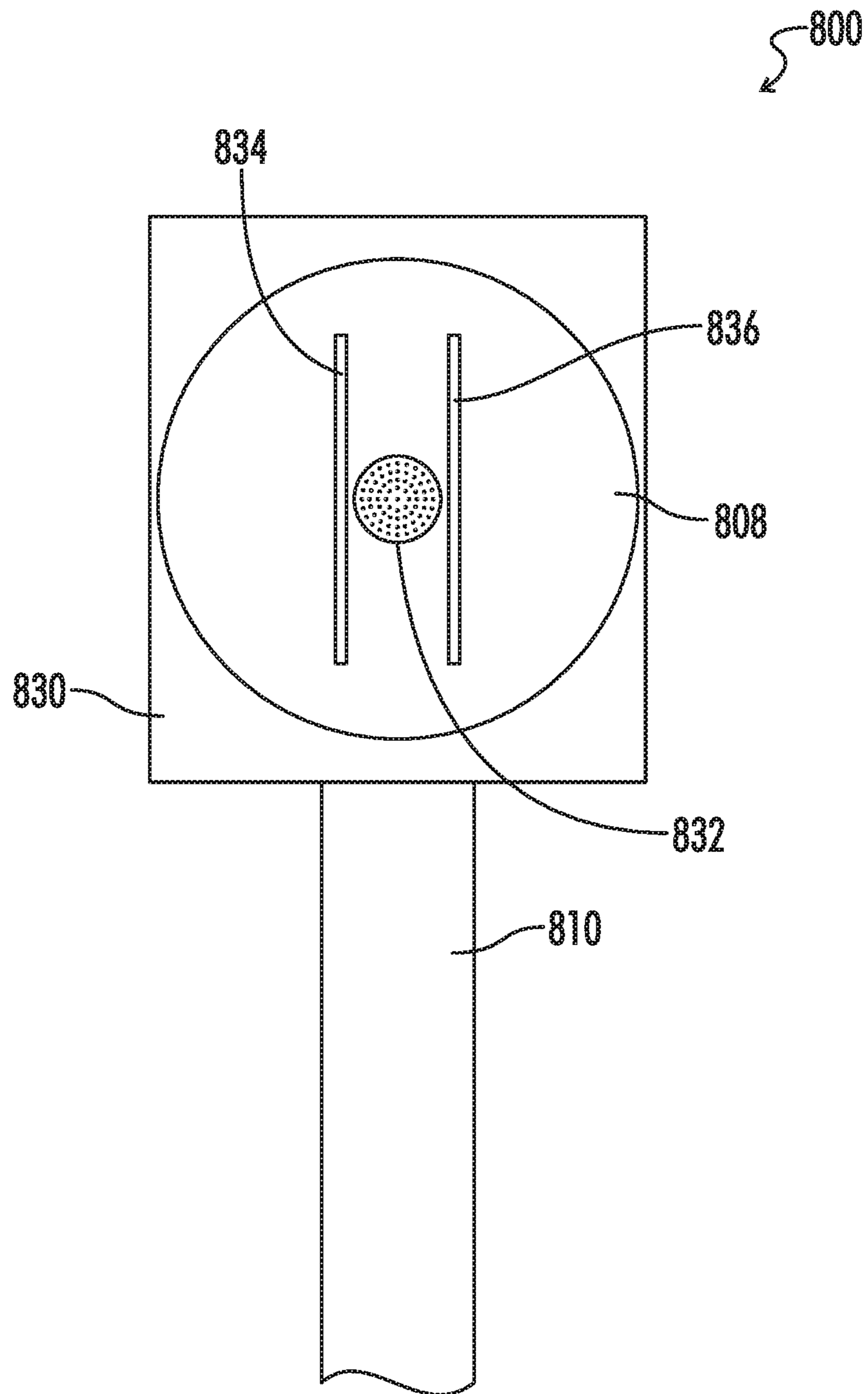
**FIG. 18**



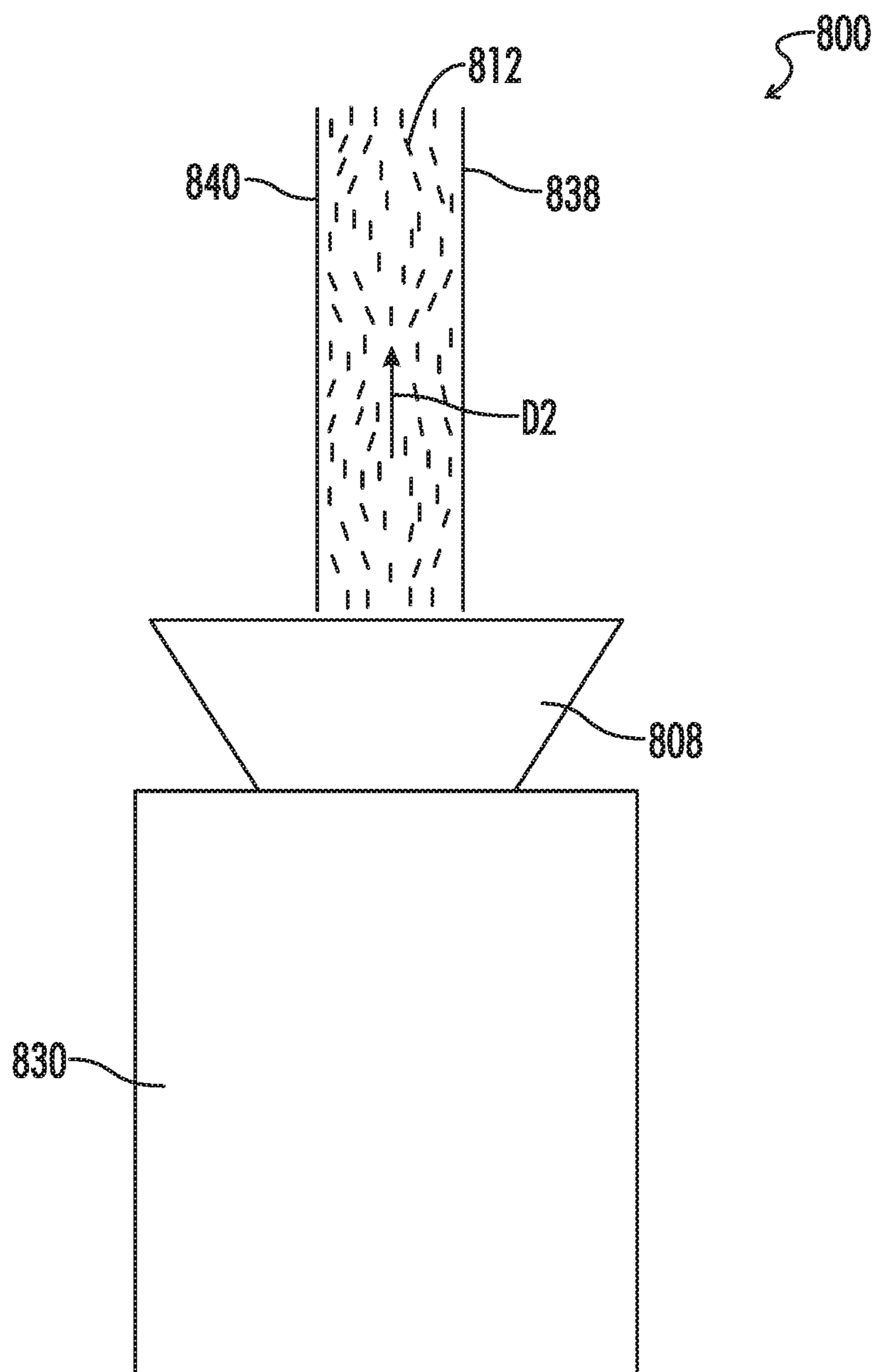
**FIG. 19**



*FIG. 20*

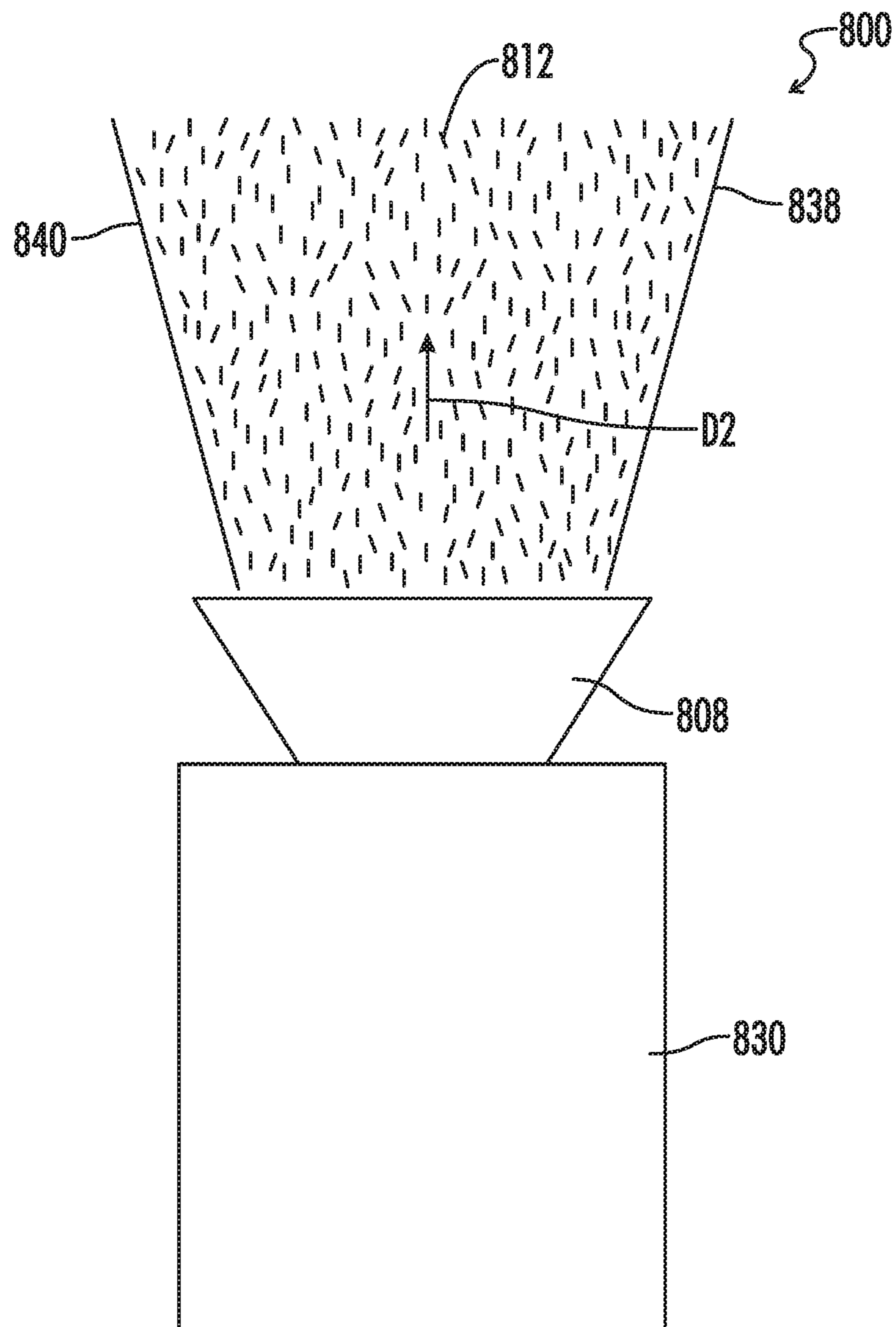


**FIG. 21**

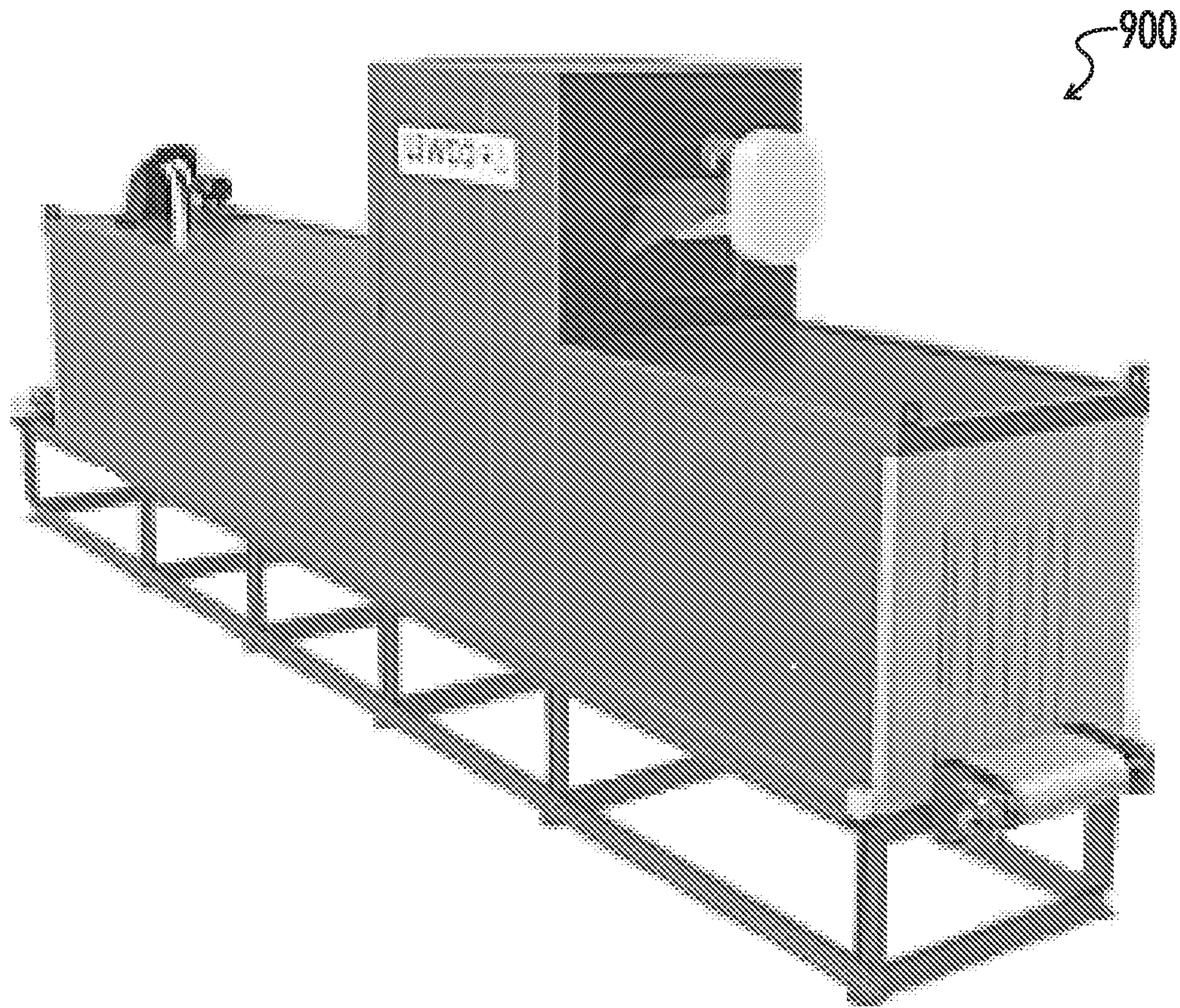


**FIG. 22**





*FIG. 23*



*FIG. 24*

## AIR BARRIER MATERIAL APPLICATION SYSTEMS AND METHODS

### BACKGROUND

The present disclosure relates generally to methods and apparatuses for building a tire. More particularly, the present disclosure pertains to building a tire without a typical inner liner and instead spraying on an air barrier material on the inner surface of the tire.

Typical pneumatic tires having inner liners are known in the art. An inner liner is used because the rubber used for the other portions of the tire is too permeable and allows air inside the tire to escape over time. The inner liner is made from a different and more expensive rubber that allows much less air to escape the tire over time. Halogenated rubbers, which are used in inner liners, are, on a pound per pound basis, the most expensive rubber in a tire. One to two pounds of inner liner rubber is used in a typical passenger tire. Concerns over expense, ease of manufacture, and ultimate finished tire weight make the typical inner liner undesirable.

What is needed, therefore, is one or more methods and apparatuses that allow for an inner liner to be sprayed onto the inner surface of the tire.

### BRIEF SUMMARY

Briefly, the present disclosure relates, in one embodiment, to a method of applying an air barrier material to an inner surface of a tire. The method may include curing the tire; securing the tire onto a chuck of a post-cure inflation machine; performing a first post-cure inflation cycle; spraying the air barrier material onto the inner surface of the tire while the tire is in a spray position within 25 degrees of vertical; and axially rotating the tire while the tire is secured on the chuck in the spray position.

The present disclosure also relates, in one embodiment, to a method of applying an air barrier material to an inner surface of a tire. The method may include performing a post-cure inflation of the tire; placing the tire onto a dump gate platform after finishing the post-cure inflation of the tire; and spraying the air barrier material onto the inner surface of the tire while the tire is on the dump gate platform.

The present disclosure further relates, in an embodiment, to a method of applying an air barrier material to an inner surface of a tire. The method may include conveying the tire to a spray area section of a conveyor system; stopping the tire on the spray area section; spraying the air barrier material onto the inner surface of the tire while the tire is stopped on the spray area section; and conveying the tire away from the spray area section after spraying the air barrier material onto the inner surface of the tire.

The present disclosure further still relates, in one embodiment, to a method of applying an air barrier material to an inner surface of a tire. The method may include placing the tire in a tire trimming machine; rotating the tire in the tire trimming machine as part of a tire trimming operation; and spraying the air barrier material onto the inner surface of the tire while performing the tire trimming operation.

The present disclosure even further relates, in one embodiment, to a sprayer apparatus for spraying an air barrier material onto an inner surface of a tire. The sprayer apparatus may include a nozzle. The nozzle may include at least one material opening defined in the nozzle. The at least one material opening may be configured to project the air barrier material in a general material direction. At least one first air projection opening may be defined in the nozzle on

a first side of the at least one material opening. At least one second air projection opening may be defined in the nozzle on a second side of the at least one material opening. The second side may be opposite the first side. The at least one first air projection opening and the at least one second air projection opening may each be configured to project a respective one of two air blades to contain the material between the air blades.

The present disclosure also relates, in one embodiment, to a post-cure inflation machine for processing a tire. The post-cure inflation machine may include a tire holder shaft. The tire holder shaft may include a chuck configured to secure the tire to the tire holder shaft. A hollow passage may be defined in the tire holder shaft. A spray nozzle may be connected to a spray shaft. The spray shaft may be telescopically disposed in the hollow passage of the tire holder shaft so that the spray nozzle may extend to spray an air barrier material onto the tire.

The present disclosure further still relates, in one embodiment, to a spray area section of a conveyor system for processing a tire. The spray area section may include a spray area platform. A sprayer passage may be defined in the spray area platform. A spray nozzle may be configured to pass through the sprayer passage so that the spray nozzle may extend to spray an air barrier material onto the tire.

The present disclosure yet further relates, in one embodiment, to a tire trimming machine for processing a tire. The tire trimming machine may include at least one centering roller configured to bias the tire into a centered position. At least one blade may be configured to trim the tire. A spray nozzle may be configured to extend to spray an air barrier material onto the tire.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of a typical pneumatic passenger tire.

FIG. 2 is a flow chart showing the typical steps of creating a pneumatic tire.

FIG. 3 is a front elevation view of an embodiment of a post-cure inflation machine for processing pneumatic tires.

FIG. 4 is a side elevation view of the post-cure inflation machine of FIG. 3 with a first tire undergoing a first post-cure inflation cycle and a second tire not yet mounted to the post-cure inflation machine.

FIG. 5 is a side elevation view of the post-cure inflation machine of FIG. 3. This figure could show the first tire undergoing a second post-cure inflation cycle and the second tire undergoing a first post-cure inflation cycle. Alternatively, this figure could show the first tire undergoing a first post-cure inflation cycle and the second tire having been just recently mounted to the post-cure inflation machine.

FIG. 6 is a side elevation view of the post-cure inflation machine of FIG. 3. This figure shows the post-cure inflation machine at a spraying step wherein the tire being sprayed is in the spray position.

FIG. 7 is a front elevation view of an embodiment of a spray area section of a conveyor system, the spray area section including a dump gate.

FIG. 8 is a side elevation view of the spray area section of FIG. 7 with the sprayer in the retracted position.

FIG. 9 is a side elevation view of the spray area section of FIG. 7 with the sprayer in the extended position.

FIG. 10 is a side elevation view of an embodiment of a spray area section of a conveyor system showing a receiving conveyor and a horizontally mounted sprayer, the spray area section including a dump gate.

FIG. 11 is a side elevation view of the spray area section of FIG. 10 with the dump gate holding the tire in a vertical position while the sprayer applies the air barrier material.

FIG. 12 is a side elevation view of the spray area section of FIG. 10 with the dump gate in a dump position to transfer the tire to the receiving conveyor after the tire has been sprayed with the air barrier material.

FIG. 13 is a side elevation view of the spray area section of FIG. 10 with the dump gate in the start position to receive a new tire after the previous tire has been transferred to the receiving conveyor.

FIG. 14 is a front elevation view of an embodiment of a spray area section of a conveyor system showing a delivery conveyor and a receiving conveyor. The spray area section being similar to that shown in FIGS. 7-9, but with no dump gate.

FIG. 15 is a front elevation view of an embodiment of a spray area section of a conveyor system showing a delivery conveyor and a receiving conveyor.

FIG. 16 is a side elevation view of the spray area section of FIG. 15. The spray area section being similar to that shown in FIGS. 10 and 11, but with no dump gate and with a differently located receiving conveyor.

FIG. 17 is a perspective view of an embodiment of a tire trimming machine.

FIG. 18 is a cross-sectional view of the tire trimming machine of FIG. 17 including a sprayer in a retracted position.

FIG. 19 is a cross-sectional view of the tire trimming machine of FIG. 17 with the sprayer in an extended position and spraying an air barrier material onto a tire.

FIG. 20 is a perspective view of a spray booth for spraying an air barrier material onto a tire.

FIG. 21 is a front elevation view of a spray apparatus for spraying an air barrier material onto an inner surface of a tire.

FIG. 22 is a top plan view of the spray apparatus of FIG. 21 while spraying the air barrier material.

FIG. 23 is a top plan view of another configuration of the spray apparatus of FIG. 21 while spraying the air barrier material.

FIG. 24 is a perspective view of a conveyor oven.

### DETAILED DESCRIPTION

Reference will now be made in detail to embodiments of the present disclosure, one or more drawings of which are set forth herein. Each drawing is provided by way of explanation of the present disclosure and is not a limitation. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made to the teachings of the present disclosure without departing from the scope of the disclosure. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment.

Thus, it is intended that the present disclosure covers such modifications and variations as come within the scope of the appended claims and their equivalents. Other objects, features, and aspects of the present disclosure are disclosed in, or are obvious from, the following detailed description. It is to be understood by one of ordinary skill in the art that the present discussion is a description of exemplary embodiments only and is not intended as limiting the broader aspects of the present disclosure.

The words “connected”, “attached”, “joined”, “mounted”, “fastened”, and the like should be interpreted to mean any manner of joining two objects including, but not limited to,

the use of any fasteners such as screws, nuts and bolts, bolts, pin and clevis, and the like allowing for a stationary, translatable, or pivotable relationship; welding of any kind such as traditional MIG welding, TIG welding, friction welding, brazing, soldering, ultrasonic welding, torch welding, inductive welding, and the like; using any resin, glue, epoxy, and the like; being integrally formed as a single part together; any mechanical fit such as a friction fit, interference fit, slidable fit, rotatable fit, pivotable fit, and the like; any combination thereof; and the like.

The words “vertical” and “horizontal” are used for clarity of language to aid in understanding the disclosure. These words are in reference to orientations of the components when being viewed in an upright position and do not limit any of the claims to only the upright position. Vertical may, in some embodiments, be associated with an axis along the direction of gravity. Horizontal, then, may be associated with an axis that is perpendicular thereto. The terms substantially vertical and substantially horizontal may refer to a range that is about true vertical and true horizontal. Substantially vertical should be understood to be any orientation with an absolute angle up to 25 degrees, and more preferably up to 15 degrees, from an axis along the direction of gravity. Substantially horizontal should be understood to be any orientation with an absolute angle of up to 25 degrees, and more preferably up to 15 degrees, from an axis perpendicular to the direction of gravity.

Unless specifically stated otherwise, any part of the apparatus of the present disclosure may be made of any appropriate or suitable material including, but not limited to, metal, alloy, polymer, polymer mixture, wood, composite, or any combination thereof.

Referring to FIG. 1, a typical pneumatic passenger tire 11 is shown. The tire 11 may be multi-layered and may include tire beads 13, body plies 15, at least one cushion 17, steel belts 19, at least one belt wedge 21, gum strips 23, nylon overlays 25, undertread 27, sidewalls 29, and a tread portion 31. The typical pneumatic passenger tire 11 also includes an inner liner 33, often a halobutyl, chlorobutyl, or bromobutyl liner. This inner liner 33 is used because the rubber used for the other portions of the tire 11 is too permeable and allows air inside the tire to escape over time. The inner liner 33 is made from a different and more expensive rubber that allows much less air to escape the tire over time. Halogenated rubbers, which are used in inner liners 33, are, on a pound per pound basis, the most expensive rubber in a tire 11. One to two pounds of inner liner rubber is used in a typical passenger tire 11.

As shown in FIG. 2, a typical pneumatic passenger tire 11 is created according to the schematic tire build process. At steps 1 and 2, the raw materials are prepared for the building process. At step 3, the fabric cord is calendered and cut into plies, and the steel belt is calendered and cut. At step 4, the bead is assembled. At step 5, the tread and sidewall is extruded, and the inner liner is calendered. At step 6, the tire is built. At step 7, the tire is cured. At step 8, the tire is inspected in multiple fashions. Finally, the tire is finished and ready for use or sale.

### Post-Cure Inflation Machine and Method Relating Thereto

Turning now to FIGS. 3-6, a post-cure inflation machine 100 is shown. The post-cure inflation machine 100 may receive a tire 35 (with no inner liner) that has recently been cured in a curing press (not shown).

## 5

At least one tire holder shaft **102** of the post-cure inflation machine **100** may include a chuck **104**. The chuck **104** may be configured to secure the tire **35** to the tire holder shaft **102**. At least one of the tire holder shaft **102** and the chuck **104** may be configured to rotate about an axis **A1** of the tire holder shaft in some embodiments.

A hollow passage **106** may be defined in the tire holder shaft **102**. A spray nozzle **108** may be connected to a spray shaft **110**. The spray shaft **110** may be telescopically disposed in the hollow passage **106** of the tire holder shaft **102**. This configuration may allow the spray nozzle to extend to spray an air barrier material **112** onto the tire **35**.

In some embodiments, the spray nozzle **108** and spray shaft **110** may be rigidly connected to a portion of the tire holder shaft **102**. The tire holder shaft **102** may be telescopic itself in many embodiments. The spray shaft **110** may also be configured to extend telescopically along the axis **A1** of the tire holder shaft **102**. Additionally or alternatively, the spray shaft **110** may be configured to extend telescopically in a direction perpendicular to the axis **A1** of the tire holder shaft **102**.

A method of applying the air barrier material **112** to an inner surface **37** of the tire **35** may be performed with the above described post-cure inflation machine **100**. The method may include curing the tire **35**, often with a curing press.

After the tire **35** has been cured, the tire may be secured onto the chuck **104** of the post-cure inflation machine **100**. The tire **35** may be placed on the tire holder shaft **102** by a robotic arm or a person. The tire **35** may be placed on the tire holder shaft **102** at the middle-right of FIG. **3**, for instance. Once the tire **35** has been received on the tire holder shaft **102**, the chuck **104** may be actuated to secure the tire.

Once the tire **35** is secured by the chuck **104**, the tire holder shaft **102** may rotate around an extender arm axis **A2** to position the tire holder shaft to receive another tire on the other end of the tire holder shaft. Additionally or alternatively, the tire holder shaft **102** may rotate around a base axis **A3**. The ends of the tire holder shaft **102** may rotate about the extender arm axis **A2** along a path **114** as shown in FIGS. **4-6**.

Once the tire holder shaft **102** has rotated once to place the tire **35** in a first position that is substantially horizontal, the tire begins its first post-cure inflation cycle. The bottom tire **35** on FIG. **4** is in the first position, for instance. While the bottom tire **35** is undergoing its first post-cure inflation cycle, another tire may be placed on the top part of the tire holder shaft **102** as shown in FIG. **5**.

Between some or all rotations, the tire holder shaft **102** may stop at a spray position that is substantially horizontal as shown in FIG. **6**. The tire **35**, then, is substantially vertical. The bottom tire **35** of FIG. **5**, having completed its first post-cure inflation cycle, may rotate to this spray position on the left of FIG. **6**. At this position, the tire **35** may receive a coating of air barrier material **112** sprayed from the spray nozzle **108**. In many embodiments, the tire **35** may be rotated about the axis **A1** of the tire holder shaft during and/or after the spraying process.

In some embodiments, the spray nozzle **108** may extend from inside the tire holder shaft **102** such that the spray nozzle is directed at the inner surface **37** of the tire **35**. In these embodiments, the spray nozzle **108** may retract back inside the tire holder shaft **102** after completing the spraying task.

## 6

After the spraying step is finished, the tire **35** may then move to a second position, the top position of the two tires shown in FIG. **5**, to undergo a second post-cure inflation cycle.

5 Additionally or alternatively, the tires **35** may receive a coating of air barrier material **112** sprayed from the spray nozzle **108** after the second post-cure inflation cycle. In some embodiments, the tire **35** may receive a coating of air barrier material **112** sprayed from the spray nozzle **108** during the second post-cure inflation cycle.

#### Dump Gate Assembly and Method Relating Thereto

15 In FIGS. **7-9**, an embodiment of a spray area section **200** of a conveyor system is shown. With regard to FIGS. **7-9**, the spray area section **200** is a dump gate assembly.

The dump gate assembly **200** may include a dump gate platform **202** for supporting the tire **35**. In many embodiments, the dump gate platform **202** may include a plurality of rollers **204**. The rollers **204** may be of any appropriate construction and may include bar rollers, ball bearing type rollers, conveyor belts, wheels, actuated sections of the spray area platform **202**, and the like.

25 A spray passage **206** may be defined in the dump gate platform **202**. This spray passage **206** may, in some embodiments, include a missing roller **204** or a gap between rollers, conveyor belts, and the like. A spray nozzle **208** may be configured to pass through the spray passage **206**. The spray nozzle **208** may extend from below the dump gate platform **202** to above the dump gate platform by a telescopic spray shaft **210** in some embodiments. The spray nozzle **208** may extend to a position to spray an air barrier material **212** onto the tire **35**.

35 A dump gate wall **214** may be positioned substantially orthogonally to the dump gate platform **202**. The dump gate wall **214** may also include rollers **204** of any appropriate construction. At least one drive roller **216** may be disposed on the dump gate wall **214** to rotate the tire **35** about the tire axis **A4** on the dump gate platform **202**. The rest of the rollers **204** disposed on the dump gate wall **214** and the dump gate platform **202** may be configured to allow this rotation of the tire **35**. Additionally or alternatively, the spray nozzle **208** may be configured to rotate on the spray shaft **210** during the spray operation.

A method of applying the air barrier material **212** to an inner surface **37** of the tire **35** may be performed with the above described spray area section **200**. The method may include performing a post-cure inflation of the tire **35**.

50 After the post-cure inflation process has been completed, the tire **35** may be placed on the dump gate platform **202**. The tire **35** may be placed on the dump gate platform **202** by a robotic arm or a person.

55 While the tire **35** is on the dump gate platform **202**, the air barrier material **212** is sprayed onto the inner surface **37** of the tire. This step may be accomplished by first extending the spray nozzle **208** from below the dump gate platform **202**. In some embodiments, the spray shaft **210** is telescopically elongated to extend the spray nozzle **208**. The spray nozzle **208** may then be directed at the inner surface **37** of the tire **35**. After the spraying step is completed, the spray nozzle **208** may be retracted back to a position below the dump gate platform **202**. In some embodiments, the spray shaft **210** telescopically retracts to retract the spray nozzle **208**.

65 The tire **35** may then be removed from the dump gate assembly **200** by a robotic arm, a person, or (as discussed

below) may be released from the dump gate assembly by rotating the dump gate wall **214** away from the dump gate platform **202** to allow the tire to fall and come to rest on a conveyor belt.

Another embodiment of a spray area section, or dump gate assembly, **300** of a conveyor system is shown in FIGS. **10-13**.

Like components to those shown in FIGS. **7-9** with respect to the dump gate assembly **200** are repeated in FIGS. **10-13** with a reference numeral that begins with a three instead of a two. As such, some of the reference numerals shown in FIGS. **10-13** may not otherwise be mentioned herein.

The dump gate assembly **300** may not include an opening or passage in the dump gate platform **302**. Instead, the dump gate assembly **300** may be configured to move from a first position (shown in FIGS. **10** and **13**) with the dump gate platform **302** substantially horizontal to a second position (shown in FIG. **11**) with the dump gate platform substantially vertical. With the dump gate platform **302** in the second position, the tire **35** is also positioned substantially vertically and rests on the dump gate wall **314**.

The spray shaft **310** may be mounted to a sprayer tower **318** such that the spray nozzle **308** may extend substantially parallel with the ground toward the tire **35**.

As discussed briefly above, the dump gate wall **314** may be configured to rotate in a direction **D1** (up and into the page of FIG. **12**) away from the dump gate platform **302** to allow the tire **35** to fall and come to rest on a conveyor belt **320**. The conveyor belt **320** may be positioned to receive the tire **35** and to carry the tire away from the dump gate assembly **300** and toward another component of the tire manufacturing process.

A method of applying the air barrier material **312** to an inner surface **37** of the tire **35** may be performed with the above described spray area section **300**. The method may include performing a post-cure inflation of the tire **35**.

After the post-cure inflation process has been completed, the tire **35** may be placed on the dump gate platform **302**. The tire **35** may be placed on the dump gate platform **302** by a robotic arm or a person.

The tire may come to rest on the dump gate platform **302** in a first position that is substantially horizontal, as shown in FIG. **10**. Next, as shown in FIG. **11**, the tire may be moved into a spray position that is substantially vertical. This step may be accomplished by rotating the dump gate assembly **300** about a pivot point **322**. This rotation may be accomplished by a motor connected to a portion of the dump gate assembly **300**, a human actuating the rotation, and the like. Once the tire is in the substantially vertical position, the spray nozzle **308** extends toward the tire **35** such that the spray nozzle may spray air barrier material **312** onto the inner surface **37** of the tire. A spraying step is performed while the tire **35** is rotated about its axis **A4** by the at least one drive roller **316** on the dump gate wall **314**. After the spraying step is completed, the spray nozzle **308** retracts toward the spray tower **318**, and the dump gate assembly **300** is rotated back to the first position, as shown in FIG. **10**. Additionally or alternatively, the dump gate assembly **300** may be rotated to the release position, as shown in FIG. **12**. In the release position, the dump gate wall **314** may be rotated in a direction **D1** (represented by an arrow indicating up and into the page of FIG. **12**) such that it no longer obstructs the tire **35** in its path to the conveyor belt **320**. After the tire has passed to the conveyor belt **320**, the dump gate assembly **300** moves back to the first position to receive the next tire, as shown in FIG. **13**.

## Conveyor System Assembly and Method Relating Thereto

Another embodiment of a spray area section **400** of a conveyor system **424** is shown in FIG. **14**.

Like components to those shown in FIGS. **7-9** with respect to the dump gate assembly **200** are repeated in FIG. **14** with a reference numeral that begins with a four instead of a two with regard to the spray area section **400**. As such, some of the reference numerals shown in FIG. **14** may not otherwise be mentioned herein.

The spray area section **400** may function largely in the same way as the dump gate assembly **200**, except the spray area section may not include the release function as discussed above with regard to the dump gate assemblies **200**, **300**. Instead, the spray area section **400** may be configured to receive the tire **35** from an upstream portion of the conveyor system **424**. The spray area section **400** may also be configured to deliver the tire **35** to a downstream portion of the conveyor system **424**. The portions of the conveyor system **424** other than the spray area section **400** may include a conveyor belt **420**, rollers **404**, wheels, actuated portions of a platform, a shaker table, and the like.

A method of applying the air barrier material **412** to an inner surface **37** of the tire **35** may be performed with the spray area section **400**. This method may include conveying the tire to the spray area section **400** of a conveyor system **424**. After the tire **35** has reached the spray area section **400**, the tire is stopped. This stopping function may be performed by an unactuated drive roller **416** in the spray area platform **402** or by a drive roller briefly rolling in a direction opposite the direction of the tire's momentum. While the tire **35** is stopped on the spray area section **400**, the spray nozzle **408** extends from below the spray area platform **402** to above the spray area platform. The spray nozzle **408** sprays air barrier material (not shown) onto the inner surface **37** of the tire. After the spraying step is completed, the spray nozzle **408** retracts back to below the spray area platform **402**. The tire is then conveyed away from the spray area section **400**. This conveyance may be initiated by a drive roller **416** in the spray area platform **402**, and the tire **35** may be further carried away by downstream rollers **404** (or a conveyor belt, wheels, actuated portions of a platform, shaker tables, and the like).

In some embodiments, one or more drive rollers **416** in the spray area wall **414** may rotate the tire about its axis **A4** during the spray operation. Additionally or alternatively, the spray nozzle **408** may rotate about the spray shaft **410** during the spray operation.

Another embodiment of a spray area section **500** of a conveyor system **524** is shown in FIGS. **15** and **16**.

Like components to those shown in FIGS. **10-13** with respect to the dump gate assembly **300** are repeated in FIGS. **15** and **16** with a reference numeral that begins with a five instead of a three. As such, some of the reference numerals shown in FIGS. **15** and **16** may not otherwise be mentioned herein.

The spray area section **500** may function largely in the same way as the dump gate assembly **300**, except the spray area section may not include the release function as discussed above with regard to the dump gate assemblies **200**, **300**. Instead, the spray area section **500** may be configured to receive the tire **35** from an upstream portion of the conveyor system **524** and to deliver the tire to a downstream portion of the conveyor system (like conveyor system **424** of FIG. **14** discussed above).

A method of applying the air barrier material **512** to an inner surface **37** of the tire **35** may be performed with the spray area section **500**. This method may include conveying the tire to the spray area section **500** of a conveyor system **524**. After the tire **35** has reached the spray area section **500**, the tire is stopped in a manner similar to the spray area section **400**. The tire is stopped on the spray area platform **502** in a substantially horizontal position (shown in FIGS. **15** and **16**). While the tire is stopped on the spray area platform **502**, the tire is moved to a spray position that is substantially vertical (similar to the dump gate assembly **300** shown in FIG. **11**) by rotating the spray area section **500** about the pivot point **522**. In the spray position, the tire **35** may be supported by the rollers **504** including at least one drive roller **516** of the spray area wall **514**. Also similar to the discussion above with regard to the dump gate assembly **300**, the tire **35** may be rotated about its axis **A4** by actuating the at least one drive roller **516**. While the tire **35** is rotating, the air barrier material is sprayed from the spray nozzle **508** to coat the inner surface **37** of the tire. When the spraying step is completed, the tire **35** returns to the substantially horizontal position by rotating the spray area section **500** about the pivot point **522** once more. Once the tire **35** has returned to the substantially horizontal position, as shown in FIGS. **15** and **16**, the tire is then conveyed away from the spray area section **500**. As with the spray area section **400** discussed above, a drive roller **516** in the spray area platform **502** may move the tire **35** to downstream rollers **504** and the like.

#### Tire Trimming Machine and Method Relating Thereto

In FIGS. **17-19**, an embodiment of a tire trimming machine **600** is shown. The tire trimming machine **600** may include at least one tire receiving platform **602**. The tire support platform may include rollers **604** in the form of conveyor belts, wheels, bearings, and the like. The rollers **604** may also be driven rollers **616** to move the tire **35** into the correct position. The tire receiving platform **602** may include a sprayer passage **606** to allow a spray nozzle **608** to extend from below the tire support platform to above the tire support platform. The spray nozzle **608** may be extended by a telescoping spray shaft **610** such that the spray nozzle may direct air barrier material **612** at the inner surface **37** of the tire **35**.

The tire trimming machine **600** may further include at least one centering roller **626**. The centering roller **626** may be configured to bias the tire **35** into a centered position (as shown in FIGS. **18** and **19**). In some embodiments, the centering roller **626** may include one or more conical rollers. The centering rollers may also include drive rollers **616** such that the tire is rotated about its axis **A4**.

At least one blade **628** may be configured to trim the tire **35** as it spins about its axis **A4**.

Although the tire trimming machine **600** is shown configured to maintain the tire **35** in a substantially horizontal position, it is contemplated that another embodiment of a tire trimming machine may maintain the tire in a substantially vertical position. It is even contemplated that an embodiment of a tire trimming machine may receive the tire **35** in a substantially horizontal position, move the tire to a substantially vertical position for the spraying operation, and return the tire to the substantially horizontal position before conveying the tire away from the tire trimming machine. In

such embodiments, the at least one centering roller **626** may be further configured to hold the tire **35** in a first position that is substantially vertical.

A method of applying the air barrier material **612** to an inner surface **37** of the tire **35** may be performed with the tire trimming machine **600**. This method may include placing the tire **35** in the tire trimming machine **600**. Once the tire **35** is in place, centering the tire in the tire trimming machine **600** with at least one centering roller **626**. After the tire **35** has been centered, rotating the tire in the tire trimming machine with at least one drive roller **616** as part of a tire trimming operation. Either prior to starting to rotate the tire **35** about its axis **A4** or while the tire is rotating, extending the spray nozzle **608** from below the tire receiving platform **602** to above the tire receiving platform such that the spray nozzle is directed at the inner surface **37** of the tire. While trimming the tire **35** with the at least one blade **628**, spraying the air barrier material **612** onto the inner surface **37** of the tire. After the spraying operation is completed, retracting the spray nozzle **608** back to below the tire receiving platform **602**.

#### Spray Booth and Method Relating Thereto

In FIG. **20**, an embodiment of a spray booth **700** is shown. The spray booth **700** may be a designated location for spraying the air barrier material **712** onto the tire **35** to prevent overspray. The spray nozzle **708** may be mounted to a portion of the spray booth **700** by the spray shaft **710**. In some embodiments, the spray shaft **710** may be telescopic such that the spray shaft may extend and retract to position the spray nozzle **708** correctly depending on the size of the tire **35** placed in the spray booth. The spray booth **700** may be a part of the assembly line of the tire **35**, or it may be separate from such an assembly line. A robotic arm or a human may place the tire **35** in the spray booth and may similarly remove the tire from the spray booth after the spraying operation has completed. The spray booth **700** may be a partial or complete enclosure, depending on the embodiment. The tire **35** may rotate about its axis **A4**, or the spray nozzle **708** may rotate about the spray shaft **710**, or both during the spraying operation.

Although the spray booth **700** is shown configured to maintain the tire **35** in a substantially horizontal position, it is contemplated that another embodiment of a spray booth may maintain the tire in a substantially vertical position. It is even contemplated that an embodiment of a spray booth may receive the tire **35** in a substantially horizontal position, move the tire to a substantially vertical position for the spraying operation, and return the tire to the substantially horizontal position before conveying the tire away from the spray booth.

#### Sprayer Apparatus and Method Related Thereto

As shown in FIGS. **21-23**, any of the spray nozzles **108**, **208**, **308**, **408**, **508**, **608**, and **708** and spray shafts **110**, **210**, **310**, **410**, **510**, **610**, and **710** discussed herein may be of a particular construction in some embodiments.

A sprayer apparatus **800** for spraying an air barrier material **812** may include a spray nozzle **808** and a spray shaft **810**. The spray nozzle **808** may be part of a spray head **830**.

The spray nozzle **808** may include at least one material opening **832** defined in the nozzle. The at least one material opening **832** may be configured to project the air barrier material **812** in a general material direction **D2**.

At least one first air projection opening **834** may be defined in the spray nozzle **808** on a first side of the at least one material opening **832**. At least one second air projection opening **836** may be defined in the spray nozzle **808** on a second side of the at least one material opening **832**. The second side may be opposite the first side. The at least one first air projection opening **834** may be configured to project a first air blade **838**. The at least one second air projection opening **836** may be configured to project a second air blade **840**. The at least two air blades **838, 840** may be configured to contain the air barrier material **812** therebetween.

As shown in FIG. **22**, the air blades **838, 840** may be directed substantially parallel to the general material direction **D2** such that the air barrier material **812** projects substantially completely parallel to the general material direction. As shown in FIG. **23**, however, the spray nozzle **808** may alternatively be configured such that the air blades **838, 840** form angles with respect to the general material direction **D2**. In this configuration, the air barrier material **812** may project in a more fanned out pattern along the general material direction **D2**. In further still configurations, the spray nozzle **808** may include air blades **838, 840** (and perhaps additional air blades) positioned and aimed such that FIG. **22** represents a side view of the spray pattern and FIG. **23** represents a top view of the spray pattern.

More than two air blades **838, 840** are contemplated herein. Less than two air blades **838, 840** is also contemplated. In some embodiments, the air blades may be of a proper number to form any polygonal shape about the at least one material opening **832**. In one embodiment, the air blade may be formed by a single opening forming a circle about the at least one material opening **832**. No matter the number of air blades, the air projection opening(s) are configured to form a virtual spray enclosure for the air barrier material **812**.

#### Air Barrier Material Curing Oven

The current disclosure contemplates a need for baking the tire **35** having the inner surface **37** coated with an air barrier material in order to cure the air barrier material. As such, a conveyor type curing oven **900** is shown in FIG. **23**. This conveyor type curing oven **900** would allow the tires **35** to continue moving along an assembly line. It is also contemplated, however, that the tires **35** could be removed from the assembly line, placed in a large oven (for instance, a walk-in, heated room), cured for a period of time, removed, and returned to the assembly line.

It is also contemplated that embodiments of the air barrier material currently developed or hereinafter developed may not require curing with an oven of any sort. In embodiments with self-curing air barrier material, no oven would be required.

This written description uses examples to disclose the invention and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal lan-

guage of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

Although embodiments of the disclosure have been described using specific terms, such description is for illustrative purposes only. The words used are words of description rather than limitation. It is to be understood that changes and variations may be made by those of ordinary skill in the art without departing from the spirit or the scope of the present disclosure, which is set forth in the following claims. In addition, it should be understood that aspects of the various embodiments may be interchanged in whole or in part. While specific uses for the subject matter of the disclosure have been exemplified, other uses are contemplated. Therefore, the spirit and scope of the appended claims should not be limited to the description of the versions contained herein.

What is claimed is:

1. A method of applying an air barrier material to an inner surface of a tire, the method comprising:

- (a) curing the tire;
- (b) after curing the tire, securing the tire onto a chuck of a post-cure inflation machine;
- (c) performing a first post-cure inflation cycle;
- (d) spraying the air barrier material onto the inner surface of the tire while the tire is in a spray position within 25 degrees of vertical; and
- (e) axially rotating the tire while the tire is secured on the chuck in the spray position.

2. The method of claim 1, wherein the first post-cure inflation cycle is performed with the tire in a first position within 25 degrees of horizontal.

3. The method of claim 2, wherein step (d) includes extending a spray nozzle from inside a shaft connected to the chuck of the post-cure inflation machine such that the spray nozzle is directed at the inner surface of the tire.

4. The method of claim 3, further comprising: after completing step (c), moving the tire to the spray position; and

after completing step (d), moving the tire to a second position within 25 degrees of horizontal to commence a second post-cure inflation cycle.

5. The method of claim 3, wherein at least a portion of a second post-cure inflation cycle is performed during step (d).

6. The method of claim 3, further comprising: after completing step (d), retracting the spray nozzle back inside the shaft of the post-cure inflation machine.

7. The method of claim 3, further comprising: moving the tire to a second position within 25 degrees of horizontal after completing step (c); performing a second post-cure inflation cycle with the tire at the second position;

moving the tire to the spray position after the second post-cure inflation cycle; and performing steps (d) and (e) after the tire is moved to the spray position from the second position.

8. The method of claim 1, wherein steps (d) and (e) overlap temporally.

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